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Dear Readers,

As usual it gives us enormous pleasure to introduce the first issue of this year's volume of Montenegrin Journal of Sports Science and Medicine (MJSSM). We will standardly review the reached achievements in the previous year and bring you some personal insight into the reasons why MJSSM is such a great journal and you should cooperate with us.

We have to strengthen that our journal continues facing the great success. Even though our Journal has entered two strongest index databases (Web of Science and Scopus), one of these databases (Scopus) continue recognizing the development of our journal that is proved by reaching high impact scores for the third year (CiteScore 2019: 2.80, SJR 2019: 0.309; SNIP 2019: 0.453), while the ongoing tracker is promising better CiteScore calculation in 2020 (CiteScoreTracker 2020: 3.00; updated on 07 February, 2021) which is scheduled for Spring 2021. On the other hand, we are still preparing our journal to be evaluated again by Web of Science to reach a long-lasting and eager impact factor and inclusion in SCIE (Science Citation Index Expended) and SSCI (Social Science Citation Index) databases. Therefore, we believe that 2021 will be the year of our highest reach, mostly because we have worked hard and that we deserve further progress and visibility at the international level as current Web of Science Citation Report is promising us success (Total Publications: 105; h-index: 9; Average citations per item: 2.93; Sum of Times Cited: 308; Without self-citations: 293; Citing articles: 210; Without self-citations: 198; updated on 07 February, 2021). Nevertheless, we must keep in mind that this success has not only been achieved by the management of the journal, our editors, reviewers and authors, as well as readers, have contributed equally. So, we want to thank all the participants in the rapid development of our journal again and again, and to invite all those who have not participated before, to join us in the future, to continue in the same rhythm to the same direction.

We would also like to discuss in the introduction speech about the journal statistics. The acceptance rate was a bit smaller, it was decreased for two more per cents from last preview. Currently, it is on 7% for original research submitted in period 2019-2020 and expected to keep decreasing for the upcoming period as we have more and more submissions every day. On the other hand, the time from submission to first decision is a little bit decreased (41 days), while the time from submission to publication is a bit increased (65 days).

From year to year, volume to volume and issue to issue, it is enormously important to repeat that our journal will continue working on growing academic publication in the fields of sports science and medicine; all clinical aspects of exercise, health, and sport; exercise physiology and biophysical investigation of sports performance; sport biomechanics; sports nutrition; rehabilitation, physiotherapy; sports psychology; sport pedagogy, sport history, sport philosophy, sport sociology, sport management; and all aspects of scientific support of the sports coaches from the natural, social and humanistic side, in various formats: original papers, review papers, editorials, short reports, peer review - fair review, as well as invited papers and award papers, as well as promote all other academic activities of Montenegrin Sports Academy and Faculty for Sport and Physical Education at University of Montenegro, such as publishing of academic books, conference proceedings, brochures etc.

As we usually do at the end of the introduction speech, we thank our authors one more time, who have chosen precisely our Journal to publish their manuscripts, and we would like to invite them to continue our cooperation to our mutual satisfaction. Thank you all of you for reading us and we hope you will find this issue of MJSSM informative enough.

Editors-in-Chief,
Prof Dusko Bjelica, PhD
Assoc. Prof Stevo Popovic, PhD

ORIGINAL SCIENTIFIC PAPER

Effect of Acute Sodium Bicarbonate Intake on Sprint-Intermittent Performance and Blood Biochemical Responses in Well-Trained Sprinters

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Abstract

The present study was designed to determine the acute effect of sodium bicarbonate ($NaHCO_3$) on the number of sprint repetitions during sprint high-intensity intermittent testing. In addition, blood biochemical (pH, HCO_3^-, and lactate) responses measured in three occasions were investigated. Thirteen male well-trained sprinters (24.65±3.44 yrs) performed two consecutive trials (7 days apart). Athletes were assigned randomly either to ingest a single dose of $NaHCO_3$ (0.3 g/kg) 1 h prior to exercise or placebo using a double-blind crossover design. The intermittent sprint test consisted of 60 s treadmill sprints (90% of maximal work done) and 30-s recovery repeated intermittently until volitional exhaustion. Blood samples were collected from all athletes before exercise, after 1 h of dose intake, and after exercise in each trial. Paired sample t-testing showed that athletes complete significantly more sprint repetitions ($p=0.036$) during the intermittent sprint test with $NaHCO_3$ (6.846±3.114) than with the placebo (5.538±3.872). Data also revealed no differences between trials in all blood responses at pre-exercise. After 1 h of dose consumption, however, blood pH and HCO_3^- were higher with $NaHCO_3$ than with placebo ($p<0.05$), but no differences were noted in lactate between trials ($p>0.05$). After completion of the test, all blood responses were significantly higher with $NaHCO_3$ than with placebo ($p<0.05$). In conclusion, intake of 0.3 g/kg of $NaHCO_3$ 1 h prior to treadmill sprint-intermittent performance increased sprint repetitions in well-trained sprinters, probably due to activated glycolysis caused by intracellular protons efflux into the blood.

Keywords: *glycolytic enzymes, blood pH, buffering capacity, contractile force, fatigue*

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Introduction

High-intensity intermittent exercise results in a pronounced accumulation of glycolytic metabolites as a consequence of anaerobic energy delivery in the working muscles (da Silva et al., 2019; Danaher, Gerber, Wellard, & Stathis, 2014; Coso, Hamouti, Agudo-Jimenez, & Mora-Rodriguez, 2010; Sweeney, Wright, Brice, & Doberstein, 2010). As exercise progresses, the production of hydrogen cations (H^+) increas-

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Conflict of interest: None declared.

es (Saunders et al., 2017) and the pH of the muscle declines (Hobson, Saunders, Ball, Harris, & Sale, 2012), which leads to acid-base imbalance. Increased acidity of the working muscles caused by H^+ accumulation is a major cause of fatigue (Debold, Fitts, Sundberg, & Nosek, 2016; Fitts, 2016; Bishop, Edge, Davis, & Goodman, 2004) and can lead to performance impairments when exercise is performed at high intensities (de Salles Painelli et al., 2013; Tobias et al., 2013; Robergs, Hutchinson, Hendee, Madden, & Siegler, 2005). More specifically, muscle acidosis has been shown to impair energy transfer via the anaerobic system (da Silva et al., 2019), disrupt phosphorylcreatine (PCr) resynthesis (Sahlin, Harris, & Hultman, 1975), and to inhibit the activity of key glycolytic enzymes, such as glycogen phosphorylase and phosphofructokinase (da Silva et al., 2019). Subsequently, the ability of the muscles to cope with high-energy demands decreases (Gladden, 2004).

Although a great portion of the contraction-induced H^+ is rapidly transported out of the working myocytes to blood and buffered by bicarbonate (HCO_3^-) (de Salles Painelli et al., 2013; Requena, Zabala, Padial, & Feriche, 2005), blood acidosis could also contribute to fatigue indirectly during high-intensity exercise (Price, Moss, & Prance, 2003; Hobson et al., 2012). In this context, nutritional supplements have been shown to attenuate acidosis and delay fatigue; sodium bicarbonate ($NaHCO_3$) is one of them.

$NaHCO_3$ is the most frequently alkalotic agent used by athletes who reliance on glycolysis to delay fatigue (da Silva et al., 2019; Saunders et al. 2017) and reduce ratings of perceived exertion (RPE) (Carr, Slater, Gore, Dawson, & Burke, 2011). $NaHCO_3$ can increase the extracellular buffering capacity by increasing blood HCO_3^- concentration (de Salles Painelli et al., 2013; Oliveira et al., 2017) in which it enhances H^+ efflux from the working muscles to the blood (da Silva et al., 2019; de Salles Painelli et al., 2013) where they are neutralized (Bishop et al., 2004).

Several investigations have shown that increased circulation-buffering capacity, achieved either by acute (single dose) or chronic (supplementation) $NaHCO_3$ intake, improves performance and capacity at high intensities (Carr et al., 2011; Requena et al., 2005; Tobias et al., 2013; Lancha Junior, de Salles Painelli, Saunders, & Artioli, 2015). This indicates that $NaHCO_3$ has been reported to be beneficial in events with high-intensity exercise lasting from approximately 1 to 5 minutes (Carr et al., 2011; Saunders et al., 2017; Tobias et al., 2013), with utilized dose ranging from 0.1 to 0.5 g/kg body mass (McNaughton, Backx, Palmer, & Strange, 1999). The mechanism proposed to be reasonable for the effect of $NaHCO_3$ involves increased activation of the glycolytic and the adenosine triphosphate (ATP)-PCr systems (Deb, Gough, Sparks, & McNaughton, 2018), although elevation in blood lactate has been demonstrated following $NaHCO_3$ intake (Artioli et al., 2007).

Studies using repeated sprint bouts of high-intensity exercise have observed performance improvement (Price et al., 2003; Bishop et al., 2004; Tobias et al., 2013; Deb et al., 2018), but others failed to report beneficial effects (de Araujo Dias et al., 2015; de Salles Painelli et al., 2013; da Silva et al., 2019). Beside of discrepancies associated with the beneficial effect of $NaHCO_3$, high volume and intensity exercise could induce acid-base disturbances (Carr et al., 2013). Additionally, although $NaHCO_3$ has been studied for years, most investigations have been conducted using cycling ergometer tests. However, the effect of $NaHCO_3$ intake on blood responses during repeated sprint-intermittent testing on a treadmill remains poorly investigated, and its effect on exercise capacity has yet to be demonstrated. Therefore, this study aimed to determine the number of sprint repetitions during treadmill high-intensity intermittent exercise protocol until volitional exhaustion. A secondary aim of this study was to investigate the concentrations of blood pH, HCO_3^-, and lactate in response to exercise. We hypothesized that extracellular buffering capacity by ingesting acute $NaHCO_3$ might attenuate blood acidity and improve performance.

Methods

Participants

Thirteen male well-trained sprinting athletes (see Table 1 for participants demographic data) volunteered to participate in the present study, following being informed about the potential risks and benefits involved in participation. All athletes had been involved in a sprinting training at the Jordan Military Sports Federation for a minimum of five years. Other inclusion criteria for participation were the following: long male athletes; age ranged 20-30 years old; no previous injuries for at least four months, and not consuming $NaHCO_3$ or any ergogenic aids seven days prior to participation. This study was approved in advance by the local scientific research committee of Yarmouk University (protocol. 11-2019 M.A). Each participant voluntarily provided written informed consent before participation.

Table 1. Participants' demographic data

Variables	Mean ± SD
Age (years)	24.65 ± 3.44
Height (cm)	181.55 ± 4.74
Mass (kg)	79.34 ± 5.22
BMI (kg/m²)	24.30 ± 2.46
resting HR (bpm)	63.67 ± 3.92
Training volume (min/week)	420.33 ± 48.61
Training experience (years)	6.23 ± 1.98
100-m best time (s)	10.43 ± 0.60

Experimental design

Athletes performed two experimental trials in which they ingested a single dose of $NaHCO_3$ (Premium sodium bicarbonate powder, VITADIRECT, USA) or maltodextrin (placebo). The trials were randomized and separated by one week to complete recovery, with both trials performed at the same time of the day (07.45 AM) to ensure that the findings were not affected by circadian rhythm. $NaHCO_3$ and placebo were coded before data collection. The doses were administered in a crossover design, with the double-blind provision of $NaHCO_3$ and placebo, as neither examiners nor athletes were aware of the experimental treatment. Each trial consisted of 1) intake

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of $NaHCO_3$ or placebo in the laboratory one hour prior to exercise, 2) a standardized 10-min warm-up (treadmill jogging with a speed of 7-8 km/h, joint mobilization, and stretching), and 3) repeated intermittent sprint test on a treadmill. Athletes were instructed to refrain from drinking water during the trial. The exercise protocol in both trials was performed in a cool environment (20-22˚C) and 42-45% relative humidity.

Experimental procedure

Each athlete visited the laboratory on four different occasions. Athletes' characteristics and vital factors were measured on the first visit. On the second visit, each athlete engaged in a warm-up to prepare themselves for running on a treadmill (Technogym Excite + RUN 1000-19" LED Touchscreen, Italy). They engaged in running three bouts with different speeds that ranged from low to moderate (7-13 km/h) for 10 min. On the next day (third visit), each athlete was familiarized with running on the treadmill for 15 min. After a 5 min rest, the athletes underwent a graded exercise test to determine VO_{2max}, in which exercise intensity is progressively increased while measuring ventilation and oxygen and carbon dioxide concentration of the inhaled and exhaled air. VO_{2max} is reached when oxygen consumption remains at a steady state despite an increase in workload (see Price et al., 2003). This regimen was done to measure the athletes' greater speed (intensity) associated with VO_{2max} while performing in each trial for a 60 s sprint. Determination of VO_{2max} was to know the efficacy of cardiopulmonary status and to indicate a preparedness of athletes' ability to perform the intermittent sprint test effectively. The results of athletes' VO_{2max} and greater treadmill speed were 59.36±3.61 ml/kg/min; 17.05±1.71 km/h, respectively.

On the fourth visit, we repeated the regimen for each athlete to confirm the intensity (speed) of the exercise. Test-retest showed no difference in VO_{2max} (t=2.14, p=0.32) and maximal speed (t=0.65, p=0.73). Athletes then asked to perform the intermittent sprint test at a speed of 90% of their achieved maximal speed (range: 16.6-17.5 km/h). The tests were measured over three days.

All athletes were instructed to refrain from strenuous exercise in the 48 hours prior to each trial and also abstaining from drinking coffee for 12 hours. They were asked to avoid breakfast (eating) before beginning a trial to limit confounding nutritional effect on performance and to ensure $NaHCO_3$ absorption. Each athlete was asked to drink 500 ml of water 90 min prior to each trial to prevent possible dehydration.

$NaHCO_3$ and placebo intake protocol

Athletes were instructed to ingest 0.3 g/kg of $NaHCO_3$ orally 1 h prior to the experimental trial. $NaHCO_3$ was administered in 400 ml of chilled water (16 ˚C) and mixed with 30 ml of strawberry flavour. The selected dose was used to avoid possible confounding factors that may impede performance. An intake acute dose of $NaHCO_3$ greater than 0.5 g/kg body mass can cause abdominal pain, flatulence, nausea, vomiting, and diarrhoea (Lancha Junior et al., 2015). In addition, all athletes were requested to ingest the supplement within 10 minutes to optimal absorption (Deb et al., 2018). In the placebo trial, athletes were asked to complete the same order with maltodextrin. The supplements were ingested using indistinguishable bottles so that the participants did not know which drink they had ingested.

Sprint-intermittent test

The intermittent sprint test consisted of treadmill repeated 60-s sprint bouts until volitional exhaustion (task failure). Rest periods were 30s between bouts. A speed of 16.6-17.5 km/h (the range of athletes' maximal speed) was maintained in the treadmill throughout the bouts, in which the athletes were encouraged to complete as many as possible repetitions successfully. Task failure defined as the inability to maintain sprinting within 10 seconds of the preferred cadence.

Blood samples collection and analysis

The blood samples were collected from each participant in both trials to measure blood pH, HCO_3^-, and lactate on three occasions: pre-exercise, post-1 h of dose intake, and post-exercise. Venipuncture was used to obtain blood samples (4 ml). Blood pH and HCO_3^- were analysed using an ABL800 radiometer (Denmark). Blood lactate concentration was analysed using an Integral 400 device (Switzerland). The reference ranges of variables were as follows: 0.63-2.44 mmol/L for lactate, 22.0-29.0 mmol/L for HCO_3^-. The normal blood pH is tightly regulated between 7.35 and 7.45.

Statistical analysis

The Shapiro-Wilk test was applied to check for normal distribution. All variables (blood pH, HCO_3^-, and lactate) at the three time points were normally distributed (p>0.05). A repeated measures analysis of variance (ANOVA) with a Greenhouse-Geisser correction was used to determine possible differences in blood responses at the three time points within a trial. When a significant F rate was achieved, a post hoc test using the Bonferroni correction was used for pairwise comparison using adjusted means. A paired sample t-test was used to analyse the differences in the number of sprint repetitions between trials, and to analyse the differences in each measured point between trials. Frequentist inferences were assessed against the mean difference ± 95% confidence interval CI between trials in which that variances do not cross the zero-boundary interpreted as significant. All descriptive data are reported as mean ± SD. Significance was set at P<0.05 for all analyses. Statistical analysis was conducted using SPSS version 18.0 and Microsoft Excel.

Results

Data revealed that the number of sprint repetitions during the intermittent sprint test were significantly greater with $NaHCO_3$ (6.846±3.114) than with the placebo (5.538±3.872) (t=4.113, p=0.036). Table 2 illustrates the results of blood biochemical responses to the $NaHCO_3$ at three time points: 1) pre-exercise, 2) 1 h after dose intake, and 3) post-exercise. The analysed data showed statistical differences in all blood responses. Post hoc using Bonferroni with adjusted means revealed that both blood pH and HCO_3^- were significantly higher after 1 h of $NaHCO_3$ intake compared to pre- (F=4.201, p=0.027; F=3.817, p=0.030 for pH and HCO_3^-, respectively) and post-exercise (F=3.522, p=0.034; F=2.961, p=0.041 for pH and HCO_3^-, respectively), whereas blood lactate level was elevated after the finish of the test in comparison to the pre-exercise level (F=6.012 , p=0.003) and 1 h post-dose (F = 8.976, p = 0.001), with no differences between pre-exercise and 1 h post-dose (F=0.351, p=0.468).

Table 3 illustrates the results of blood biochemical responses to the placebo at the same three time points. Data showed differences in all blood responses. Post hoc using Bonferroni with

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Table 2. Results of blood biochemical responses to $NaHCO_3$ at baseline (pre-exercise), 1 h after ingestion, and at after exercise in 13 well-trained sprinters. Data were analysed using one-way ANOVA

Parameters	Pre-exercise	1-h post dose	Post-exercise
pH	7.42 ± 0.03	7.47 ± 0.02 [a]	7.37 ± 0.05 [a,b]
HCO_3^- (mmol/L)	25.81 ± 2.44	30.63 ± 4.01 [a]	17.28 ± 4.16 [a,b]
Lactate (mmol/L)	1.95 ± 1.88	2.21 ± 0.24	13.11 ± 3.09 [a,b]

Note. Significance level was set at p<0.05; Values expressed as mean ± SD; [a] Significantly different than pre-exercise; [b] Significantly different than 1 h post-dose.

adjusted means revealed that both blood pH and HCO_3^- were higher after 1 h of placebo intake compared to pre- (F=5.101, p=0.021; F=4.748, p=0.019 for pH and HCO_3^-, respectively) and post-exercise (F=2.676, p=0.044; F=2.11, p=0.048 for pH and HCO_3^-, respectively), with no differences between pre-exercise and 1 h post dose (F=0.589, p=0.337; F=0.343 , p=0.401). After the finish of the test, the blood lactate level was increased over the post-exercise level than pre-exercise (F=5.396, p=0.004) and 1 h post-dose (F=5.091, p=0.003), with no differences between pre-exercise and 1 h post-dose (F=0.286, p=0.573).

Table 3. Results of blood biochemical responses to placebo at baseline (pre-exercise), 1 h after ingestion, and at after exercise in 13 well-trained sprinters. Data were analysed using one-way ANOVA

Parameters	Pre-exercise	1-h post dose	Post-exercise
pH	7.43 ± 0.02	7.43 ± 0.02	7.29 ± 0.04 [a,b]
HCO_3^- (mmol/L)	25.74 ± 2.74	25.59 ± 3.22	14.56 ± 4.38 [a,b]
Lactate (mmol/L)	2.07 ± 2.33	2.27 ± 0.44	10.46 ± 4.17 [a,b]

Note. Significance level was set at p<0.05; Values expressed as mean ± SD; [a] Significantly different than pre-exercise, [b] Significantly different than 1 h post-dose.

Table 4 illustrates the results of blood biochemical responses between $NaHCO_3$ and placebo at the same three time points. There were no significant differences between trials in all blood responses at pre-exercise. After 1 h of dose consume, blood pH and HCO_3^- were higher with $NaHCO_3$ than with placebo, but no differences were noted in lactate between trials. After the finish of the test, however, all variables were significantly higher with $NaHCO_3$ than with placebo.

Table 4. Results of blood biochemical responses to $NaHCO_3$ and placebo at baseline (pre-exercise), 1 h after ingestion, and at after exercise in 13 well-trained sprinters. Data were analysed using paired sample t test

Parameters	Pre-exercise			1-h post dose			Post-exercise		
	$NaHCO_3$	Placebo	p value	$NaHCO_3$	Placebo	p value	$NaHCO_3$	Placebo	p value
pH	7.42 ± 0.03	7.43 ± 0.02	0.101	7.47 ± 0.02	7.43 ± 0.02	0.001*	7.37 ± 0.05	7.29 ± 0.04	0.001*
HCO_3^- (mmol/L)	25.81 ± 2.44	25.74 ± 2.74	0.531	30.63 ± 4.01	25.59 ± 3.22	0.002*	17.28 ± 4.16	14.56 ± 4.38	0.021*
Lactate (mmol/L)	1.95 ± 1.88	2.07 ± 2.33	0.281	2.21 ± 0.24	2.27 ± 0.44	0.347	13.11 ± 3.09	10.46 ± 4.17	0.043*

Note. Significance level was set at p<0.05; Values expressed as mean ± SD; * Significantly different from placebo.

Discussion

The primary finding of the present study was that $NaHCO_3$ ingestion was an effective strategy to complete significantly more sprint repetitions when compared to ingestion of the placebo. This result could be explained by the excessive blood HCO_3^- concentration due to $NaHCO_3$ consumed before the beginning of the trial, in which it enhances intracellular H^+ efflux. It has been documented that $NaHCO_3$ administration can attenuate roughly 62% of the H^+ diffused from working muscle cells to the blood during highly intensive exercise (Carr, Webstar, Boyed, Hudson, & Scheett, 2013; Medbo & Tabata, 1993). Additionally, $NaHCO_3$ can also contribute to delay the onset of fatigue by maintaining energy-producing capability (Carr et al., 2013; Requena et al., 2005) and/or by decreasing RPE (Tobias et al., 2013). Another explanation by which $NaHCO_3$ intake increased the number of sprint repetitions during the test is that $NaHCO_3$ could activate the actomyosin ATPase (Carr et al., 2013) and elicit a calcium release from the sarcoplasmic reticulum (Requena et al., 2005), potentiating the actomyosin coupling system, and thereby increasing muscle capacity.

The result of our study agreed with the finding of Deb et al. (2018), who showed that exercise tolerance during an intermittent exercise test (60-s work in high-intensity to exhaustion, separated by 30-s recovery interval) was significantly greater after 0.3 g/kg body mass of $NaHCO_3$ (845.3±242.4 s) compared to placebo trial (734.3±175.7 s). However, their protocol was carried out on a cycle ergometer, and the participants were recreationally active male individuals. Another study conducted by Price et al. (2003) also demonstrated that the intake of 0.3 g/kg of $NaHCO_3$ 1 h prior to exercise increased peak power (11.5 ± 5%) expressed relative to a trial of sprint testing compared to sodium chloride (NaCL, 1.8±9.5%). In the same study, participants were nonathletes and completed an incremental cycle ergometer test which consisted of two 30-min intervals (repeated 3-min blocks; 90 s at 40% VO_{2max}, 60 s at 60% VO_{2max}, 14-s maximal sprint, 16-s rest). Tobias et al. (2013) reported enhanced high-intensity intermittent upper-body performance (4 30-s Wingate test, separated by 3 min) following chronic beta-alanine (BA) supplementation (6.4 g/day for 4 weeks) combined with 500 mg/kg of $NaHCO_3$ ingested within seven days compared to a placebo in well-trained athletes. The total work done in that study was increased by 8% in the mode

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of $NaHCO_3$ supplementation, which differed from our protocol. However, it has been suggested that chronic $NaHCO_3$ can elicit muscular capacity similarly with an acute intake (Artioli et al., 2007).

Our findings were contrary to further studies. Recently, da Silva et al. (2019) showed that a combination of BA supplementation (6.4 g/day for 28 days) and acute $NaHCO_3$ (0.3 g/kg) 60 min prior to cycling time-trial (60-s bouts at 110% of maximal power output, separated by 60-s rest) did not improve performance compared to each one alone and placebo in male cyclists. However, they suggested that $NaHCO_3$ increased the estimated glycolytic ATP-PCr systems. de Salles Painelli et al. (2013) reported that 0.3 g/kg of $NaHCO_3$ intake following BA supplementation (3.2-6.4 g/day for 4 weeks) had no egrogenic effect in 100- and 200-m swimming performance in swimmers. A limitation of that study was the lack of blood HCO_3^- measurement, so they failed to suggest an explanation for non-significant performance improvement. de Araujo Dias et al. (2015) observed that the ingestion of 0.3 g/kg of $NaHCO_3$ did not affect graded high-intensity cycling capacity test which initiated at 100 W and increased by 6 W every 15 s until volitional exhaustion compared to placebo. The explanation of their finding was attributed to a variability of monocarboxylate (MCT) transporter protein activity after $NaHCO_3$ intake and to H^+ efflux ratio from myocytes into blood. However, participants recruited in that study were recreationally active individuals. In addition, conflicting findings have been observed when the duration of an exercise lasting less than 2 min (Requena et al., 2005). Danaher et al. (2014) showed no differences in repeated sprint ability (RSA) test (5 repeats of 6 s maximal effort cycling bouts, separated by 24 s rest) between $NaHCO_3$ (300 mg/kg), BA (4.8-6.4 g/day for 4 weeks) and placebo trials. However, time-to-exhaustion during cycling capacity test performed following RSA was increased 16% with a combination of $NaHCO_3$+BA. The lack of ergogenic effect of $NaHCO_3$ intake upon performance in previous studies might be associated with the type of exercise protocol, the duration of exercise, the small number of the sample, the intensity of exercise, and the environmental temperatures.

Our results showed that blood pH and HCO_3^- were significantly higher after the finish of the test in the $NaHCO_3$ trial than that of the placebo trial, which might indicate the effective buffering capacity of the extracellular median due to $NaHCO_3$ intake. Increased extracellular pH and raised HCO_3^- due to $NaHCO_3$ consume might raise the H^+ and lactate efflux from working muscles (Requena et al., 2005) by increasing the activity of the lactate-/H^+ cotransporter. This mechanism delays the drop in pH (Marx et al., 2002), delays the onset of fatigue (Hobson, et al., 2013), and leads to higher contractile force (McNaughton et al., 1999) by sustained muscle glycolytic ATP production (McKenzie, Couts, Stirling, Hoeben, & Kubara, 1986; Kemp & Foe, 1983). In this context, however, increased activation of glycolytic ATP-PCr systems induce high lactate levels (da Silva et al., 2019). Increased post-exercise lactate has been reported after $NaHCO_3$ intake (da Silva et al., 2019; Bishop et al., 2004), which might explain the elevated blood lactate after the finish of the test in the $NaHCO_3$ trial compared to the placebo in the present study. Additionally, the greater sprints repetitions as a result of $NaHCO_3$ consume was also contributed to elevation in blood lactate levels. In a study conducted by Deb et al. (2018), blood HCO_3^- was significantly higher in experimental trial after intermittent testing (16.0±2.0 mmol/L) compared to 13.0±3.0 mmol/L in a placebo trial, and blood pH was decreased from 7.47 (pre-test) to 7.31 (post-test) in $NaHCO_3$ trial compared to placebo (7.39; 7.20, respectively). In the same study, however, post-test blood lactate was significantly elevated in $NaHCO_3$ trial (17.9±5.9 mmol/L) compared to a placebo (13.9±4.3 mmol/L). da Silva et al. (2019) found that blood lactate (15.7 mmol/L), pH (7.30), and HCO_3^- (22.1 mmol/L) were significantly changed after exercise compared to placebo (12.0 mmol/L; 7.25; 19.5 mmol/l, respectively). Hobson et al. (2013) showed that chronic BA (6.4 g/day for 4 weeks) followed by acute $NaHCO_3$ (0.2 g/kg) were likely to be beneficial to 2.000-m rowing performance, with increased post-exercise blood pH, HCO_3^- and lactate compared to placebo group in rowers.

Conclusion

It can be concluded from the present data that acute (single dose) sodium bicarbonate can attenuate acidosis during high-intensity intermittent exercise and improve performance following intake 0.3 g/kg orally in well-trained sprinters, which indicates that sodium bicarbonate may act as a physicochemical buffer in the body and may represent, in part, an explanation for the ergogenic effect in sprint-intermittent exercise. Additionally, these data confirm that post-exercise blood lactate increases after the consumption of sodium bicarbonate.

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References

Artioli, G.G., Gualano, B., Coelho, D.F., Benatti, F.B., Gailey, A.W., & Lancha Jr, A.H. (2007). Does sodium-bicarbonate ingestion improve simulated judo performance? *International Journal of Sport Nutrition and Exercise Metabolism*, 17, 206-217. doi: 10.1123/ijsnem.17.2.206

Bishop, D., Edge, J., Davis, C., & Goodman, C. (2004). Induced metabolic alkalosis affects muscle metabolism and repeated sprint ability. *Medicine & Science in Sports & Exercise*, 36, 807-813. doi: 10.1249/01.MSS.0000126392.20025.17

Carr, A.J., Slater, G.J., Gore, C.J., Dawson, B., & Burke, L.M. (2011). Effect of sodium bicarbonate on [HCO_3^-], pH, and gastrointestinal symptoms. *International Journal of Nutrition and Exercise Metabolism*, 21, 189-194. doi: 10.1123/ijsnem.21.3.189

Carr, B.M., Webstar, M.J., Boyed, J.C., Hudson, G.M., & Scheett, T.P. (2013). Sodium bicarbonate supplementation improves hypertrophy-type resistance exercise performance. *European Journal of Applied Physiology*, 113, 743-752. doi: 10.1007/s00421-012-2484-8

Coso, J.D., Hamouti, N., Agudo-Jimenez, R., & Mora-Rodriguez, R. (2010). Restoration of blood pH between repeated bouts of high-intensity exercise: effects of various active-recovery protocols. *European Journal of Applied Physiology*, 108, 523-532. doi: 10.1007/s00421-009-1248-6

da Silva, R.P., de Oliveira, L.F., Saunders, B., de Andrade Kratz, C., de Salles Painelli, V., da Eira Silva, V., Marins, J.C.B., Franchini, E., Gualano, B., & Artioli, G.G. (2019). Effects of β-alanine and sodium bicarbonate supplementation on the estimated energy system contribution during high-intensity intermittent exercise. *Amino Acids*, 51, 83-96. doi: 10.1007/s00421-014-2895-9

Danaher, J., Gerber, T., Wellard, B.M., & Stathis, C.G. (2014). The effect of β-alanine and $NaHCO_3$ co-ingestion on buffering capacity and exercise performance with high-intensity exercise in healthy males. *European Journal of Applied Physiology*, 114, 1715-1724. doi: 10.1007/s00421-014-2895-9

de Araujo Dias, G.F., da Eira Silva, V., de Salles Painelli, V., Sale, C., Artioli, G.G., Gualano, B., & Saunders, B. (2015). (In) Consistencies in responses to sodium bicarbonate supplementation: a randomised, repeated measures, counterbalanced and double-blind study. *PLoS ONE*, 10(11), 1-13. doi: 10.1371/journal.pone.0143086

de Salles Painelli, V., Roschel, H., de Jesus, F., Sale, C., Harris, R.C., Solis, M.Y., Benatti, F.B., Gualano, B., Lancha Jr, A.H., & Artioli, G.G. (2013). The ergogenic effect of beta-alanine combined with sodium bicarbonate on high-intensity swimming performance. *Applied Physiology Nutrition and Metabolism*, 38, 525-532. doi: 10.1139/apnm-2012-0286

Deb, S.K., Gough, L.A., Sparks, S.A., & McNaughton, L.R. (2018). Sodium bicarbonate supplementation improves severe-intensity intermittent exercise under moderate acute hypoxia conditions. *European Journal of Applied Physiology*, 118, 607-615. doi: 10.1007/s00421-018-3801-7

Debold, E.P., Fitts, R.H., Sundberg, C.W., & Nosek, T.M. (2016). Muscle fatigue from the perspective of a single crossbridge. *Medicine & Science in Sports & Exercise*, 11, 2270-2280. doi: 10.1249/MSS.0000000000001047

Fitts, R.H. (2016). The role of acidosis in fatigue: pro perspective. *Medicine & Science in Sports & Exercise*, 11, 2335-2338. doi: 10.1249/MSS.0000000000001043

Gladden, L.B. (2004). Lactate metabolism: a new paradigm for the third millennium. *The Journal of Physiology*, 558, 5-30. doi: 10.1113/jphysiol.2003.058701

Hobson, R.M., Harris, R.C., Martin, D., Smith, P., Macklin, B., Gualano, B., & Sale, C. (2013). Effect of β-alanine with and without sodium bicarbonate on 2.000-m rowing performance. *International Journal of Sport Nutrition and Exercise Metabolism*, 23, 480-487. doi: 10.1123/ijsnem.23.5.480

Hobson, R.M., Saunders, B., Ball, G., Harris, R.C., & Sale, C. (2012). Effects of β-alanine supplementation on exercise performance: a meta-analysis. *Amino Acids*, 43, 25-37. doi: 10.1007/s00726-011-1200-z

Kemp, R.J., & Foe, L.G. (1983). Allosteric regulatory properties of muscle phosphofructokinase. *Molecular and Cellular Biochemistry*, 57, 147-154. doi: 10.1007/BF00849191

Lancha Junior, A.H., de Salles Painelli, V., Saunders, B., & Artioli, G.G. (2015). Nutritional strategies to modulate intracellular and extracellular buffering capacity during high-intensity exercise. *Sports Medicine*, 45(Suppl 1), S71-S81. doi: 10.1007/s40279-015-0397-5

Marx, J.O., Gordon, S.E., Vos, N.K., Nindl, B.C., Gomez, A.L., Volekk, J.S., Pedro, J., Ratamess, N., Newton, R.U., French, D.N., Rubin, M.R., Hakkinen, K., & Kraemer, W.J. (2002). Effect of alkalosis on plasma epinephrine responses to high intensity cycle exercise in humans. *European Journal of Applied Physiology*, 87, 72-77. doi: 10.1007/s00421-002-0591-7

McKenzie, D.C., Couts, K.D., Stirling, D.R., Hoeben, H.H., & Kubara, G. (1986). Maximal work production following two levels of artificially induced metabolic alkalosis. *Journal of Sports Sciences*, 4, 35-38. doi: 10.1080/02640418608732096

McNaughton, L., Backx, K., Palmer, G., & Strange, N. (1999). Effects of chronic bicarbonate ingestion on the performance of high-intensity work. *European Journal of Applied Physiology*, 80, 333-336. doi: 10.1007/s004210050600

Medbo, J.I., & Tabata, I. (1993). Anaerobic energy release in working muscle during 30 s to 3 min of exhausting bicycling. *Journal of Applied Physiology*, 75(4), 1654-1660. doi: 10.1152/jappl.1993.75.4.1654

Oliveira, L.F., de Salles Painelli, V., Nemezio, K., Goncalves, L.S., Yamaguchi, G., Saunders, B., Gualano, B., & Artioli, G.G. (2017). Chronic lactate supplementation does not improve blood buffering capacity and repeated high-intensity exercise. *Scandinavian Journal of Medicine and Science in Sports*, 27, 1231-1239. doi: 10.1111/sms.12792

Price, M., Moss, P., & Prance, S. (2003). Effects of sodium bicarbonate ingestion on prolonged intermittent exercise. *Medicine & Science in Sports & Exercise*, 35(8), 1303-1308. doi: 10.1249/01.MSS.0000079067.46555.3C

Requena, B., Zabala, M., Padial, P., & Feriche, B. (2005). Sodium bicarbonate and sodium citrate: ergogenic aids?. *The Journal of Strength and Conditioning Research*, 19(1), 213-224.

Robergs, R., Hutchinson, K., Hendee, S., Madden, S., & Siegler, J. (2005). Influence of pre-exercise acidosis and alkalosis on the kinetics of acid-base recovery following intense exercise. *International Journal of Sport Nutrition and Exercise Metabolism*, 15, 59-74. doi: 10.1123/ijsnem.15.1.59

Sahlin, K., Harris, R.C., & Hultman, E. (1975). Creatine kinase equilibrium and lactate content compared with muscle pH in tissue samples obtained after isometric exercise. *Biochemical Journal*, 152, 173-180. doi: 10.1042/bj1520173

Saunders, B., Elliott-Sale, K., Artioli, G.G., Swinton, P.A., Dolan, E., Roschel, H., Sale, C., & Gualano, B. (2017). β-Alanine supplementation to improve exercise capacity and performance: a systemic review and meta-analysis. *British Journal of Sports Medicine*, 51, 658-669. doi: 10.1136/bjsports-2016-096396

Sweeney, K.M., Wright, G.A., Brice, A.G., & Doberstein, S.T. (2010). The effect of β-alanine supplementation on power performance during repeated sprint activity. *Journal of Strength and Conditioning Research*, 24, 79-87. doi: 10.1519/JSC.0b013e3181c63bd5

Tobias, G., Benatti, F.B., de Salles Painelli, V., Roschel, H., Gualano, B., Sale, C., Harris, R.C., Lancha Jr, A.H., & Artioli, G.G. (2013). Additive effects of beta-alanine and sodium bicarbonate on upper-body intermittent performance. *Amino Acids*, 45, 309-317. doi: 87.236.233.3

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ORIGINAL SCIENTIFIC PAPER

Evaluation of the Use of Postural Control Strategies during Dual-Tasks of Hearing-Impaired Athletes

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Abstract

Dual-tasks are often used with postural control. These tasks, which generally target motor skills and cognitive performance, also help to determine the individual's postural control. The purpose of this study is to determine the changes in performance during the motor task, which includes the cognitive cues of the hearing-impaired athletes. A total of 31 hearing-impaired athletes (male=19, female=12) and 34 hearing-impaired sedentary people (male=18, female=16) were included voluntarily in the study. The FitLight Trainer™ system was used to determine participants' reaction time levels. The performance time of hearing-impaired male athletes was significantly lower than the hearing-impaired sedentary men in each of the three tests (Random Test: t = 4, 089, p <0.05; Cue Test: t = 3,551, p <0.05; Mixed Cue Test: t = 2, 393, p<0.05). The performance time of hearing-impaired female athletes was statistically significantly lower than that of sedentary hearing-impaired females for all protocols (Random Test: t=2,586, p<0,05; Cue Test: t=2,568, p<0.05; Mixed Cue Test: t=2,899, p<0.05). This study demonstrates that 1) hearing-impaired athletes perform postural control adjustments automatically during the motor task, and they require minimal less cognitive effort than they need to be minimally considered; 2) regular physical activities and training showed a positive development on other systems, especially the proprioceptive system, which controls balance. In future studies, dual-task reaction time values and postural control strategy comparisons should be measured among hearing-impaired athletes and athletes who do not have a hearing disability.

Keywords: *postural control, motor skill, hearing-impaired, cognitive performance, dual-task*

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Introduction

Postural control can be defined as the ability of an individual to maintain a stable posture and remain standing when problems are encountered due to environmental conditions (Gallahue, Ozmun, & Goodway, 2013). Adequate postural control requires the errorless operation of sensory systems and successful integration and regulation (Riemann & Guskiewicz, 2000). Cooperation and the integration of sensory inputs, such as visual, vestibular, and proprioceptive, are essential to ensure postural stability (de Sousa, de França Barros, & de Sousa Neto, 2012). Changes in sensory systems can also affect the structure of postural control, and postural control can be seen in a non-coordinated and impaired form (Plata, 1997). Since the vestibular system is essential in regulating postural

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control, hearing loss, vestibular system problems may affect postural control (Agmon, Lavie, & Doumas, 2017). Dual-task testing is used to test deficits in postural control; such testing requires the simultaneous performance of the motor and cognitive tasks, such as standing, leaning, and taking a step. An individual's attentional resources and data processing capacity is probably limited, and they should be distributed among other tasks (Kerr, 1982). Recent studies suggesting that postural control requires a significant amount of attention have been working on maintaining an upright position using primary postural control source and dual-task testing (Woollacott & Shumway-Cook, 2002; de Graaf-Peters, Blauw-Hospers, Dirks, Bakker, Bos, & Hadders-Algra, 2007). In sports in which secondary performance is more important for winning, postural balance reduces the amount of attention and allows the body to focus on mental and/or motor skills. Most physical activities require athletes to provide motor responses to visual information by maintaining postural control. In this sense, studying the high demand for postural mechanisms in sports might shed light on unclear postural control strategies in both body stability and simultaneous mental or motor tasks.

In contrast, data on postural control skills in hearing-impaired individuals who participated in physical activities for an extended period, or any particular sports branch, is limited. This study aimed to determine the performance time deficits of hearing-impaired athletes during cognitive-motor dual tasks. Also, since postural control interacts with other tasks simultaneously (Derlich, Kręcisz, & Kuczyński, 2011), dual-task testing is necessary to test postural control in individuals with hearing impairment. The determination of postural control of individuals with hearing-impaired via dual-task testing can be conducive to 1) a better understanding of differences between hearing-impaired athlete and sedentary individuals, 2) identifying possible effects of regular physical activity on postural control of hearing-impaired individuals, 3) the availability of a dual-task postural control protocol in hearing-impaired individuals.

Methods

Participants

A total of 65 individuals ((athletes; male (n=19): age = 21.3±2.01 years, height = 176.73±7.84 cm, weight = 74.8±6.4 kg; female (n=12): age = 22.2±2.1 years, height = 165.4±3.1 cm, weight = 63.7±8.0 kg; Experience in Sports (year) = 9 years; Total of Active Hours/Week (12 hours; 4 days a week, 3 hours per day)), and ((sedentary individuals; male (n=18): age = 22.0±197 years, height = 171.3±5.6 cm, weight = 73.6±9.0 kg; female (n=16); age = 21.6±1.6 years, height = 160.0±5.4 cm, weight = 56.3±7.9 kg)) with degrees of hearing loss between 45 and 51 dB voluntarily participated in the study. Addiction, not using walking aids, not having major pain that restricts daily functions, and not having any known health problems are some of the criteria for the individuals to participate in the study. Both groups were matched according to their sexes and level of activeness (athlete/sedentary).

Ethics

The research protocol was approved by the university's Ethics Committee (Protocol No: 43180). To be able to include in this research, participants were asked to sign a consent form by the ethics committee's approval procedure.

Data Collection

In the research, to determine participants' reaction times, the FitLight Trainer system was used. It is a wireless reaction system with eight LED lights controlled by a tablet. The sensors can be deactivated by touching the lights as well as by merely hovering over the light. Also, the system allows the lights to be configured and the reaction time of the controller to be recorded. During the test, participants were asked to touch and deactivate the light as fast as possible.

Tasks

As in the study conducted by Laessoe, Grarup, and Bangshaab (2016), by placing eight lights 1.5 metres apart in three different colours at three different locations, participants were made to push their stability limits while attempting to reach and disable the lights. Four of the lights were placed in a blue zone on a wall in front of the participants. Two of the lights were placed in the red zone to the left of the participant, and the other two lights were placed in the green zone to the right of the participant. The pairs of lights were placed at shoulder and waist height, respectively. The lights in the red and the green zone were installed 3 metres apart from each other and 0.5 metres from the wall so that the participants would not block the lights while they were standing in the middle of the setup. The participants were asked to wait in the middle of the setup. To reach the lights, participants need to change their stability limits, or participants need to move their entire body to by taking a step. (Participants were expected to perform a similar motor task with a cognitive task in three trials throughout the dual-task test. However, the use of cognitive resources varies between tasks.) In each trial, the motor task consisted of 25 repetitive reaching tasks in which the participants were to hold their hands in front of one out of eight lights/sensors to turn off the light. The lights were adjusted to go off once, and once they are deactivated, the next one would go off in 0.5 seconds. The number of activated lights in each different zone was evenly divided between each test to ensure the participants challenge their stabilities within and beyond their limits. In this manner, in all three tests, balance and postural control were challenged equally.

In the research, all three tests were different from each other in terms of cognitive demands. Participants were encouraged to use cognitive strategies with different possibilities by providing them cues about each task:

(1) The lights would be lit in random order (red, green, and blue). No cue was given as to where the next light would appear. In a cognitive sense, this test is expected to measure the reaction time of the participants.

(2) The colour of the light indicated the position of the next light. The purpose of this is to determine whether the participant was aware of the dual-tasks. If the light were red, the following light would be lit in the red zone. If the light were green, the following light would be lit in the green zone. If the light were blue, the following light would be in the blue zone.

(3) The colour of the light determines the position of the next light; however, the red and green cues were reversed. In other words, if the light were red, the following light would be in the green zone, and vice versa. The blue light, in contrast, indicates the next light would be in the blue zone. This task shows taking on cognitive skills in utilizing the given cues. The programmed order of the lights is shown in Figure 1.

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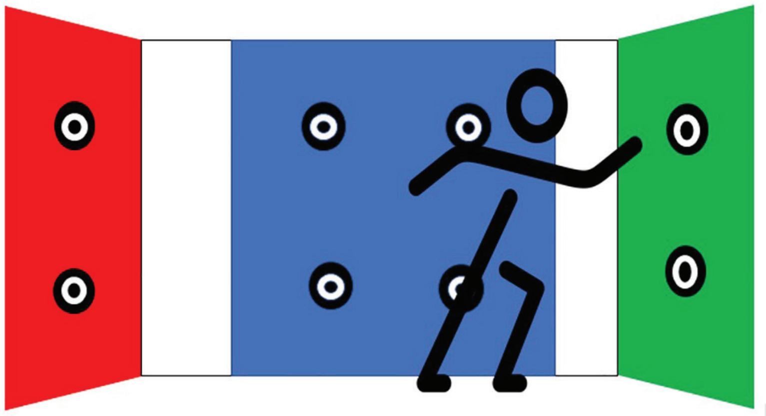

Random

Light No	8	2	3	4	1	7	2	4	8	7	8	5	2	1	7	3	1	6	4	6	5	7	2	8	1
Color	G	R	G	R	B	B	R	G	G	B	R	B	R	B	G	R	G	B	R	G	K	B	G	R	B

Cue

Light No	4	1	7	2	3	2	8	5	7	1	4	8	2	6	1	7	3	2	8	4	1	7	5	8	6
Color	R	G	R	B	R	G	B	G	R	B	G	R	B	R	G	B	R	G	B	R	G	B	G	B	B

Mixed Cue

Light No	4	1	7	2	3	2	8	5	7	1	4	8	2	6	1	7	3	2	8	4	1	7	5	8	6
Color	G	R	G	B	G	R	B	R	G	B	R	G	B	G	R	B	G	R	B	G	R	B	R	B	B

FIGURE 1. Installation. G: green zone; B: blue zone; R: red zone.

The lights were placed in three zones. Zone 1 and Zone 3 were marked as red and green, in the given order. The middle zone was blue. The light sequence was different in each test, but all lights were represented equally. In Trials 2 and 3, the colour of the light indicated the position of the following light.

The tests start with a light at a random point. All three tests were conducted in the order mentioned in the previous section. Before each test, the participants were informed about the procedure. Also, they were instructed to maintain (keeping a safe balance) their posture while they were deactivating the lights as fast as possible. The entire procedure was performed in two sessions with a 10-minute break in between. For participants to become used to the test and reliability of the research, a test-retest method was used in the study. For the validity of the research, only the data acquired from the second session were used.

Data analysis

For each test, the performance time was recorded automatically by the FitLight software and displayed on the system's control device. The figures were drawn manually entered in Excel. The data were analysed by using SPSS 23.0 (SPSS 23.0, Chicago, IL, USA). (Average times for sessions and groups are presented, and relative percentage changes are calculated for each session.) For each group and session, an average of performance time was presented, and the relative percentage values of Test 1 (random), Test 2, and Test 3 (with the cue and random cue) were calculated. The Kolmogorov-Smirnov test was used to determine if the data were distributed normally. Reliability was calculated by absolute differences between the sessions and the intraclass correlation coefficient (ICCs). The ICCs were calculated by using an absolute agreement with a two-way mixed model (ICC 3,1). These values were read according to Kappa values by Landis and Koch: <0.00 is poor, 0.00–0.20 is slight, 0.21–0.40 is fair, 0.41–0.60 is moderate, 0.61–0.80 is substantial, and 0.81–1.00 is almost perfect (Landis & Koch, 1977). To refrain from any bias opinion regarding the participants' learning capacity, and for the validity of the research, only the data collected from the second session were used. To measure the performances in all three tests, factorial repeated ANOVA was used. Scores and deficits between the tests were shown as average and confidence intervals in the charts (CI 95%). In the tests with given cues, performance improvements were evaluated according to the changes in the individual base scores. In the scope of this research, the significance level was accepted as <.05.

Results

The total and the average performance time of hearing-impaired athletes and sedentary individuals in three tests and their performance improvements in the cue given test were respectively shown in Table 1 (for female groups) and Table 3 (for male groups). The differences in average performance time between the two sessions in all three tests within the female and male groups were shown in Table 2 and Table 4, respectively. The hearing-impaired athletes and sedentary individuals' performance durations were better, as shown in Figure 2. The relative improvement in performance times are significantly different (p<0.001), and during the cue given tests, this difference was smaller in sedentary individuals. Sedentary individuals' performance was mostly lower than the athletes' in all tests; however, both groups' performance improved (shorter amount of time) during the cue given motor tasks (p<0.001). Generally, sedentary groups' tests took significantly longer than athlete groups' tests did (p<0.001). When the baseline values were compared, there were improvements in the cue given tests. Improvement in the performance duration was more evident in simple cognitive tasks compared to cross-colour cue cognitive tasks.

Table 1. Performances of Female Groups in Three Tests

	Random	Cue	Mixed Cue		Random vs Cue	Random vs Mixed Cue
			Sedentary Female			
1st Session	40.72 (4.0)	34.44 (5.4)	37.63 (5.0)		-15.43%*	-7.61%*
2nd Session	37.25 (3.2)	32.13 (4.3)	35.44 (5.2)		-13.75%*	-4.87%
				ICC	0.67 (0.22-0.88)	0.79 (0.52-0.92)
			Athletes Female			
1st Session	35.67 (1.6)	31.79 (4.7)	33.17 (3.7)		-10.87%*	-7.01%
2nd Session	34.33 (2.6)	28.18 (3.7)	30.45 (3.3)		-16.84%*	-9.72%*
				ICC	0.59 (0.10-0.87)	0.56 (0.10-0.84)

Note: *p<0.05. Total and average performance durations of female groups in three tests, and their performance improvements in the cue given tests. Time duration in seconds; average and standard deviation, increase in spent time, and average percentage (standard deviation). Negative values show performance improvements.

Time score in seconds; mean and SD, and reduction in time score, mean percentage (SD). Negative values represent performance improvements. ICC: Intra-class correlation coefficient (CI 95%).

Table 2. Value differences in Performance Durations of Female Groups in Tests

	Protocols	Group	n		Mean Differences	P
1st Session	Random	Sedentary Female	16	40.72	5,052	,000*
		Athletes Female	11	35.67	-5,052	
	Cue	Sedentary Female	16	34.44	2,643	,197
		Athletes Female	11	31.79	-2,643	
	Mixed Cue	Sedentary Female	16	37.63	4,452	,018*
		Athletes Female	11	33.17	-4,452	
2nd Session	Random	Sedentary Female	16	37.25	2.924	,016*
		Athletes Female	11	34.33	-2.924	
	Cue	Sedentary Female	16	32.13	3,955	,016*
		Athletes Female	11	28.18	-3,955	
	Mixed Cue	Sedentary Female	16	35.44	4,987	,008*
		Athletes Female	11	30.45	-4,987	

Note: *p<0.05 Value differences in performance durations and their average in Session 1 and Session 2 of the female groups in all three tests. Relative improvements in performances in cue given tests are higher in hearing-impaired female athletes compared to hearing-impaired sedentary female participants (p<0.001). Also, performance duration time is longer in hearing-impaired sedentary female participants in cross-location cue test (p<0.01; Figure 3).

Relative improvements in performances in cue given tests are higher in hearing-impaired female athletes compared to hearing-impaired sedentary female participants (p<0.001). Also, performance time is shorter in hearing-impaired female athletes in the cross-location cue test (p<0.01).

Hearing-impaired sedentary participants were generally

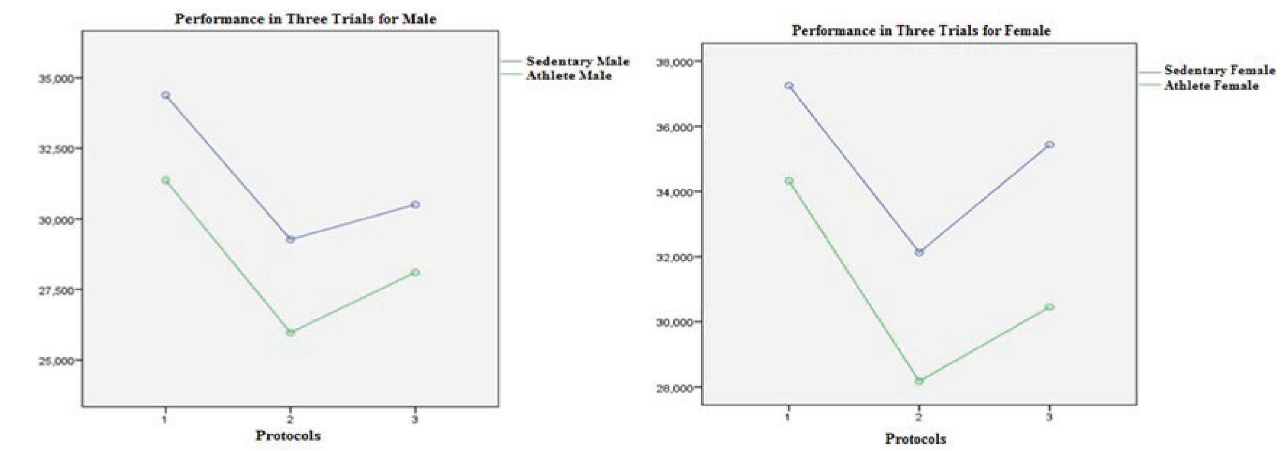

FIGURE 2. Performance Duration

slower than the hearing-impaired athletes in all trials, but both groups (sedentary and athletes) improved their performance (i.e., used shorter time) when they were provided with a leading cue (p<0.001).

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Table 3. Performances of Male Groups in Three Tests

	Random	Cue	Mixed Cue	Random vs. Cue	Random vs. Mixed Cue
		Sedentary Male			
1st Session	37.53 (2.4)	33.44 (4.5)	33.24 (3.0)	-10.90%*	-11.42%*
2nd Session	34.39 (2.2)	29.27 (3.2)	30.51 (3.4)	-14.89%*	-11.27%*
				ICC	0.51 (0.07-0.79)
		Athletes Male			
1st Session	32.89 (3.0)	28.08 (1.8)	30.37 (3.0)	-14.62%*	-7.67%*
2nd Session	31.37 (2.3)	25.97 (2.4)	28.10 (2.7)	-17.22%*	-10.42%*
				ICC	0.57 (0.08-0.83)

Note. *p<0.05. Total and average performance durations of male groups in three tests, and performance improvements in the cue given tests. Time duration in seconds; average and standard deviation, increase in spent time, and average percentage (standard deviation). Negative values show performance improvements.

Time score in seconds; mean and SD, and reduction in time score, mean percentage (SD). Negative values represent performance improvements. ICC: Intra-class correlation coefficient (CI 95%).

Table 4. Value differences in Performance Durations of Male Groups in Tests

	Protocols	Group	n		Mean Differences	P
1st Session	Random	Sedentary Male	18	37.53	4.638	0.000*
		Male Athletes	19	32.89	-4.638	
	Cue	Sedentary Male	18	33.44	5.358	0.000*
		Male Athletes	19	28.08	-5.358	
	Mixed Cue	Sedentary Male	18	33.24	2.874	0.007*
		Male Athletes	19	30.37	-2.874	
2nd Session	Random	Sedentary Male	18	34.39	3,019	0.000*
		Male Athletes	19	31.37	-3,019	
	Cue	Sedentary Male	18	29.27	3,302	0.001*
		Male Athletes	19	25.97	-3,302	
	Mixed Cue	Sedentary Male	18	30.51	2,411	0.022*
		Male Athletes	19	28.10	-2,411	

Note. *p<0.05. Value differences of performance durations and their average in Session 1 and Session 2 of the male groups in all three tests. Relative improvements in performances in cue given tests are higher in hearing-impaired male athletes compared to hearing-impaired sedentary female participants (p<0.001). Further, performance duration time is longer in hearing-impaired sedentary male participants in cross-location cue test (p<0.01; Figure 5).

Relative improvements in performances in cue given tests are higher in hearing-impaired male athletes compared to hearing-impaired sedentary male participants (p<0.001). Furthermore, performance time is shorter in hearing-impaired male athletes in the cross-location cue test (p<0.01).

Discussion

The purpose of the conducted research is to determine the changes in performance durations during motor tasks that include cognitive cues of hearing-impaired athletes. As hypothesized, the results suggest that hearing-impaired female and male athletes had better performance compared to hearing-impaired sedentary individuals in the tests with or without cues given. Furthermore, the results show that hearing-impaired sedentary individuals do not use the information in the cues. There are several possible explanations for this result. A possible satisfactory explanation for the hearing-impaired athletes' minimal decrease in the second task performance during the dual-tasks is that athletes use cognitive resources less. Considering sedentary individuals' guessing the location of the next light and using expected postural control strategies, the increase in the reaction time supports the idea of shifting focus from posture to cognition. This may be an indication of automatic postural control requiring more activity of the central nervous system, which can be explained with Abernethy's model, which shows the attentional capacity sharing hypothesis (Abernethy, 1988).

According to that model, when the primary task is more complicated, a greater portion of an individual's processing capacity needs to be shared to maintain a sustainable performance (Huang & Mercer, 2001). In our study, according to this model, since the hearing-impaired sedentary group could not use the given cues as much as the hearing-impaired athletes could, the sustained attentional capacity of the sedentary individuals might be insufficient in this research. Also, this can be explained as a result of motor tasks requiring more attention, or attentional capacity of sedentary individuals' being limited. Because exercising is simultaneously performed with not only a motor but also a cognitive task in a distracting environment, it can be pointed out that hearing-impaired athletes' motor learning process can affect the results. Also, several studies suggest that maintaining postural control is an indication of an autonomous skill level (Stins, Michielsen, Roerdink, & Beek, 2009; Donker, Roerdink, Greven, & Beek, 2007). This finding may be responsible for that fact that hearing-impaired individuals' with nine years of experience in sports show that exercising has an impact on disabled individuals' developing postural control. This also demonstrates the reason that both female and male hearing-impaired athletes performed better during the tests compared to sedentary hearing-impaired individuals since that cognitive demand is minimal for the athlete groups.

These findings generally concurred with those of previous studies; that investigated individuals with different groups of people (Howell, Beasley, Vopat, & Meehan III, 2017; Martini, Goulet, Gates, & Broglio, 2016; Howell, Osternig, & Chou, 2015). While most of the studies (Cossette, Ouellet, & McFadyen, 2014; Howell, Osternig, Koester, & Chou, 2014) are evaluated based on cognitive performance reaction time, some researchers studied walking variables and changes in the reaction time (Cossette et al., 2014). Another critical indicator used to improve stability and cognitive performance is physical exercise (Zanotto et al., 2014; Gomez-Pinilla & Hillman, 2013). Our results are consistent with the referenced results (Brown & Bennett, 2002; Park & Reuter-Lorenz, 2009; Wollesen & Voelcker-Rehage, 2014). It has been indicated that training has great importance in improving various cognitive skills and reducing cognitive-motor intervention (Brown & Bennett, 2002; Park & Reuter-Lorenz, 2009; Wollesen & Voelcker-Rehage, 2014). At the end of their research, Müller and Blischke (2009) proposed that dual-task costs are reduced by training, which allows modulation of consciousness-dependent motor activities to be more automatic. As proposed by Smith and Chambertlin (1992), soccer players ran slowly with the addition of the secondary tasks; however, they also determined that players' speed increased as the years of experience increased. In their studies, Vuillerme and Nougier (2004) have that while conducting more complicated balance tasks, expert gymnasts use less cognitive interference compared to beginners.

These results show that during testing and learning a new skill, the task components are more focused on, and this might not be the case for expert athletes who have higher skill levels. This study demonstrates that athletes who display better performance in secondary tasks can train in more complicated situations where they have to guess their opponent's moves. In contrast, it is thought that athletes who display worse performance in the secondary tasks might need more practice on basic skills during single tasks or less complicated dual-tasks.

There are a few limitations to this research. First, the number of participants can be increased. The reliability of the data will increase when there are more participants included in the research. Second, in future studies, dual-task reaction time values and postural control strategy comparisons should be measured among hearing-impaired athletes and athletes who do not have a hearing disability.

References

Abernethy, B. (1988). Dual-task methodology and motor skills research: some applications and methodological constraints. *Journal of Human Movement Studies*, *14*, 101-132.

Agmon, M., Lavie, L., & Doumas, M. (2017). The association between hearing loss, postural control, and mobility in older adults: A systematic review. *Journal of the American Academy of Audiology*, *28*(6), 575-588. doi: 10.3766/jaaa.16044

Brown, S., & Bennett, E. (2002). The role of practice and automaticity in temporal and nontemporal dual-task performance. *Psychological Research*, *66*(1), 80-89. doi: 10.1007/s004260100076

Cossette, I., Ouellet, M. C., & McFadyen, B. J. (2014). A preliminary study to identify locomotor-cognitive dual tasks that reveal persistent executive dysfunction after mild traumatic brain injury. *Archives of physical medicine and rehabilitation*, *95*(8), 1594-1597. doi: 10.1016/j.apmr.2014.03.019

de Graaf-Peters, V. B., Blauw-Hospers, C. H., Dirks, T., Bakker, H., Bos, A. F., & Hadders-Algra, M. (2007). Development of postural control in typically developing children and children with cerebral palsy: possibilities for intervention? *Neuroscience & Biobehavioral Reviews*, *31*(8), 1191-1200. doi: 10.1016/j.neubiorev.2007.04.008

de Sousa, A. M. M., de França Barros, J., & de Sousa Neto, B. M. (2012). Postural control in children with typical development and children with profound hearing loss. *International journal of general medicine*, *5*, 433. doi: 10.2147/IJGM.S28693

Derlich, M., Kręcisz, K., & Kuczyński, M. (2011). Attention demand and postural control in children with a hearing deficit. *Research in developmental disabilities*, *32*(5), 1808-1813. doi: 10.1016/j.ridd.2011.03.009

Donker, S. F., Roerdink, M., Greven, A. J., & Beek, P. J. (2007). The regularity of center-of-pressure trajectories depends on the amount of attention invested in postural control. *Experimental Brain Research,* 181, 1–11. doi: 10.1007/s00221-007-0905-4

Gallahue, D.L., Ozmun J.C. ve Goodway J.D. (2013). *Understanding motor development: Infants, children, adolescents, adults.* New York: McGraw-Hill.

Gomez-Pinilla, F., & Hillman, C. (2013). The influence of exercise on cognitive abilities. *Comprehensive Physiology*, *3*(1), 403-428. doi: 10.1002/cphy.c110063

Howell, D. R., Beasley, M., Vopat, L., & Meehan III, W. P. (2017). The effect of prior concussion history on dual-task gait following a concussion. *Journal of neurotrauma*, *34*(4), 838-844. doi: 10.1089/neu.2016.4609

Howell, D. R., Osternig, L. R., & Chou, L. S. (2015). Adolescents demonstrate greater gait balance control deficits after a concussion than young adults. *The American journal of sports medicine*, *43*(3), 625-632. doi: 10.1177/0363546514560994

Howell, D. R., Osternig, L. R., Koester, M. C., & Chou, L. S. (2014). The effect of cognitive task complexity on gait stability in adolescents following a concussion. *Experimental brain research*, *232*(6), 1773-1782. doi: 10.1007/s00221-014-3869-1

Hsiao, E. T., & Robinovitch, S. N. (1997). Common protective movements govern unexpected falls from standing height. *Journal of biomechanics*, *31*(1), 1-9. doi: 10.1016/S0021-9290(97)00114-0

Huang, H. J., & Mercer, V. S. (2001). Dual-task methodology: applications in studies of cognitive and motor performance in adults and children. *Pediatric Physical Therapy*, *13*(3), 133-140.

Kerr R. (1982). *Psychomotor Learning.* Philadelphia: Saunders College Pub.

Laessoe, U., Grarup, B., & Bangshaab, J. (2016). The use of

 DOI 10.26773/mjssm.210302

cognitive cues for anticipatory strategies in a dynamic postural control task-validation of a novel approach to dual-task testing. *PloS one*, *11*(8). doi: 10.1371/journal.pone.0157421

Landis, J. R., & Koch, G. G. (1977). An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers. *Biometrics,* 363-374. doi: 10.2307/2529786

Martini, D. N., Goulet, G. C., Gates, D. H., & Broglio, S. P. (2016). Long-term effects of adolescent concussion history on gait, across age. *Gait & posture*, *49*, 264-270. doi: 10.1016/j.gaitpost.2016.06.028

Müller, H., & Blischke, K. (2009). Motorisches Lernen. *Grundlagen der Sportpsychologie,* 159-228.

Park, D. C., & Reuter-Lorenz, P. (2009). The adaptive brain: aging and neurocognitive scaffolding. *Annual review of psychology*, 60, 173-196. doi: 10.1146/annurev.psych.59.103006.093656

Plata, AE. (1997). Understanding the roles of vision in the control of human locomotion. *Gait Posture.* 5, 54-69. doi: 10.1016/S0966-6362(96)01109-5

Riemann, B. L., & Guskiewicz, K. M. (2000). Effects of mild head injury on postural stability as measured through clinical balance testing. *Journal of athletic training,* 35(1), 19.

Robinovitch, S. N., Hayes, W. C., & McMahon, T. A. (1991). Prediction of femoral impact forces in falls on the hip. *Journal of biomechanical engineering*, *113*(4), 366-374. doi: 10.1115/1.2895414

Smith, M. D., & Chambertlin, C. J. (1992). Effect of adding cognitively demanding tasks on soccer skill performance. *Perceptual and Motor Skills,* 75, 955–961. doi: 10.2466/pms.1992.75.3.955

Stins, J. F., Michielsen, M. E., Roerdink, M., & Beek, P. J. (2009). Sway regularity reflects attentional involvement in postural control: Effects of expertise, vision, and cognition. *Gait & Posture*, *30*(1), 106-109. doi: 10.1016/j.gaitpost.2009.04.001

Vuillerme, N., & Nougier, V. (2004). Attentional demand for regulating postural sway: The effect of expertise in gymnastics. *Brain Research Bulletin,* 63(2), 161–165. doi: 10.1016/j.brainresbull.2004.02.006

Wollesen, B., & Voelcker-Rehage, C. (2014). Training effects on motor–cognitive dual-task performance in older adults. *European Review of Aging and Physical Activity*, *11*(1), 5. doi: 10.1007/s11556-013-0122-z

Woollacott, M., & Shumway-Cook, A. (2002). Attention and the control of posture and gait: a review of an emerging area of research. *Gait & posture*, *16*(1), 1-14. doi: 10.1016/S0966-6362(01)00156-4

Zanotto, T., Bergamin, M., Roman, F., C Sieverdes, J., Gobbo, S., Zaccaria, M., & Ermolao, A. (2014). Effect of exercise on dual-task and balance on the elderly in multiple disease conditions. *Current aging science*, *7*(2), 115-136. doi: 10.2174/1874609807666140328095544

ORIGINAL SCIENTIFIC PAPER

Game-Centred Study Using Eigenvector Centrality in High-Level Women's Volleyball: Play Efficacy is Independent of Game Patterns… Or is it?

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Abstract

In sports, it is often assumed that distinct game patterns may influence the outcome of the play differently. However, a few articles about men's volleyball have suggested that play efficacy may rely more on the quality of individual attack actions, and not on game patterns. Therefore, the goal of this paper was to scrutinize if and how game patterns influence play efficacy in high-level women's volleyball. Eigenvector Centrality was assessed to integrate direct and indirect relationships between games actions. Thirteen matches from the women's World Grand Prix'2015 were analysed (46 sets; 2,016 plays). Actions were categorized according to game complex (K0 to KV) and three levels of the efficacy of each play: error, continuity, and point. The results showed that play efficacy was independent of game patterns (the central pattern was non-ideal setting conditions in all complexes and preference for using slow attacks in the extremities of the net). There were, however, some regularities for each game complex. For example, while in KI to KIII, Zone 4 was the most used attack zone, in KIV and KV there was a complete inversion to Zone 2. Moreover, results revealed that women's volleyball games are more predictable in relation to the play space (attack zones) while increasing the risk through enhanced game speed (attack tempo), in comparison with what studies in men's volleyball have shown. Future studies should consider situational variables (e.g., match status, home vs away matches), and individual players' actions should be considered in order to understand their relationships with team patterns better.

Keywords: *performance analysis, network analysis, efficacy, game complexes, game patterns*

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Introduction

The quest for improving sports performance has motivated research focused on using Match Analysis (MA) to reveal performance indicators that provide a broader understanding of the game and, consequently, deliver novel know-how and tools for optimizing training processes (O'Donoghue, 2009). Analysis of the efficacy of game actions has been very well researched in sports (Mesquita, Palao, Marcelino, and Afonso, 2013; Silva, Marcelino, Lacerda, and João, 2016). In attempting to find correlates of efficacy, research has focused on the

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analysis of movement patterns, player position, competitive level, scoring system, gender, opposition quality, match status, match local, match outcome, among others potentially contributing factors (Marcelino, Sampaio, and Mesquita, 2011; Silva et al., 2016).

In this vein, Social Network Analysis (SNA) has been regarded with growing interest in the sports context (Wäsche, Dickson, Woll, Brandes, 2017; Yamamoto & Yokoyama, 2011). Although there are six-dimensions in a conceptual typology of SNA applications (see Wäsche et al., 2017), competition networks (informing about the competitive outcome through patterns of interaction between athletes and/or teams) and interaction networks (how the relationships established between the players alter the outcome) are predominant in sports. Within SNA, Eigenvector Centrality is a measure that assists in establishing a more detailed relational overview of a network, since it properly weights both the direct and indirect connections of the nodes (see Bonacich and Lloyd (2001); Wasserman and Faust (1994), which is important, because in team sports game actions can produce diverse direct and indirect consequences (Cotta, Mora, Merelo, & Merelo-Molina, 2013). Furthermore, it is possible to use SNA to treat game actions as nodes and their relations as edges, and research in volleyball has adopted both this game-centred approach and the application of Eigenvector Centrality (Hurst et al., 2016; Laporta, Afonso, & Mesquita, 2018a, 2018b; Loureiro et al., 2017). However, only one has used eigenvector centrality to understand how game patterns influence play efficacy in high-level men's volleyball, analysing the games of the 2015 men's World League Final Phase (Laporta, Afonso, Valongo, & Mesquita, 2019).

A wide body of research has suggested that different game patterns may be associated with debilitated opposition and therefore increase the chances of success (e.g., Marcelino, Mesquita, and Afonso (2008); Mesquita and Graça (2002). However, the study of Laporta et al. (2019) showed that play efficacy was independent of game patterns in high-level men's volleyball, perhaps due to a stronger reliance on the individual skill of the attackers (Afonso & Mesquita, 2011; Mesquita & Graça, 2002), which might be explained by the fact that volleyball is a sport in which the teams cannot invade the opponents' space; therefore, the attacker will ultimately have some room for acting without a very pressing opposition (Mesquita & Graça, 2002; Queiroga, Matias, Greco, Graça, & Mesquita, 2005).

Some researchers have used SNA and adopted different analysis metrics considering the relationship between direct and indirect connections in high-level women's and men's volleyball (Hurst et al., 2016; Loureiro et al., 2017). However, these studies, despite simultaneously considering both connections, do not provide a global game view, fragmenting into smaller frames, (i.e., the relationship between some game complexes). Nevertheless, only one study carried out on men's volleyball analysed the game flow through the global game relationships (both direct and indirect) to understand the play's efficacy (Laporta et al., 2019), making it pertinent to conduct studies in women's volleyball. Therefore, the purpose of this follow-up study was to understand if and how different game patterns impact the efficacy of each play in high-level women's volleyball, following the methodology we previously used in our study of high-level men's volleyball (Laporta et al., 2019).

Methods

Participants

The sample totalled 2,049 plays (46 sets) from 13 matches of the final phase of the 2015 Edition of the World Grand Prix (teams: Brazil, USA, Italy, China, Japan and Russia), with 2,016 actions. The network was built with 127 nodes and 2153 edges. A play should not be mistaken for a rally: the former refers to each ball possession on the part of a team, while the latter is the collection of plays within the same disputed point. This study was approved by the Ethics Committee at the Centre of Research, Education, Innovation and Intervention in Sport of University of Porto (CEFADE 16.2017).

Measures

Game Complex (K) encompassed: K0 (serve), KI (side-out), KII (side-out transition), KIII (transition), KIV (attack coverage) and KV (freeball/downball) (Hurst et al., 2016; Laporta et al., 2018a; Loureiro et al., 2017). In Complex 0, Initial Position of the Server (i.e., Zones 1, 6 or 5) (Quiroga et al., 2010) and Serve Type were considered: float jump serve (i.e., without ball rotation), jump serve (i.e., with ball rotation) and standing serve (i.e., without jumping) adapted from the work of Costa, Afonso, Brant, and Mesquita (2012).

The Zone of First Contact emerged in Complexes I, II, and III and followed the six zones defined of the court as defined by FIVB rule, but added the Others Zone (OT), corresponding to the area outside the court, where the athlete can recover the ball after a touch in the block, for example. In Complexes II and III, Block Opposition was adapted from Afonso and Mesquita (2011): i) BO - no-block, ii) B1 - simple Block, iii) B2 - double block; and iv) B3 - triple block.

The following variables appear in Complexes I, II, III, IV, and V. Setting Condition evaluates the relative quality of the first contact, linking it with the attacking options: (i) A - all attack options available; (ii) B – some attack options, such as crossings, are not possible but quick attacks are; and (iii) C – the setter can only use high sets (adapted from Hurst et al. (2016)). Attack Zone was evaluated according to the FIVB official zones – (Zones 1 to 6). Attack Tempo concerns the synchronization between setter and attacker: i) Tempo 1 - attacker jumped before/same time to the set; ii) Tempo 2 - two steps approach is performed by the attacker after the set; and iii) Tempo 3 - the attacker waited for the ball (ascend movement) and after that executed a three- or more-steps approach (simplified from G. Costa et al. (2012).

Specifically, in Complex IV, the following variables were considered: Available Players Before Attack Coverage showed the available players to attack before of the attack coverage happened (adapted by Laporta, Nikolaidis, Thomas, & Afonso (2015)); Number of Coverage Lines was analysed the imaginary lines (from the net until the endline) created by the players in defence position at the attack moment (Laporta et al., 2015). In Complex V, the Freeball (offensive organization after the ball that will have to be returned softly by the opponent, due to poor conditions for performing the third contact) and Downball (attacker was unfavourable to attack, but still can perform a standing spike) (Loureiro et al., 2017); and KV Target Zone (the zone where the ball landed being an offensive or defensive zone).

The Efficacy of each game complex reported the outcome of each complex: i) E0 - error; ii) E1 - continuity; and iii) E2 – scoring a point (Laporta et al., 2019).

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Table 1. Synthesis of variables, categories and codes

Variable	Category	For Example
Game Complexes (K's)	K0-KV	KI
Initial Position of the Server	Zones 1, 6 or 5	K0SZ5
Serve Type	Float Jump, Jump and Standing.	K0STJ
Zone of First Contact (reception or defence)	FIVB Six official zones; Others Zone, OT	KIFC1
Setting Conditions	SC A; SC B and SC C.	KISCA
Attack Zone	FIVB Six official zones	KIAZ3
Attack tempo	AT 1, AT 2 and AT 3	KIAT1
Block Opposition	BO - no-block; B1 - individual block; B2 - double block; and B3 - triple block.	KIINB11
Available Players Before Attack Coverage	KIVAP1, KIVAP2, KIVAP3 and KIVAP4.	KIVAP1
Number of Coverage Lines	KIVL1, KIVL2, KIVL3 and KIVL4	KIVL2
Freeball or Downball	KVD and KVF	KVD
KV Target Zone	KVAZ (offensive) and KVDZ (defensive zone).	KVAZ
Play Efficacy	E0 - error; E1 - continuity of action; and E2 – scoring a point.	

Note: The code begins with the complex that the action took place (K0-KV); shortly thereafter, the abbreviation of the variable and lastly its category. For example, K0STJ - Serve Type - Jump in K0.

Design and Procedures

Matches were obtained from the websites laola.tv and youtube.com, recorded from a lateral side view of the court (aligned with the net with movement on both sides) in high definition (1080p). The instrument was previously validated, tested and applied by Laporta et al. (2018a); (2018b); Laporta et al. (2019).

Statistical Analysis

A descriptive analysis was conducted to ensure data quality (verify input errors, data frequency and others). Social Network Analysis techniques were applied using Gephi© 0.8.2-beta for Mac (Version 10.10.3, MacRoman, France). Nodes' size and colour were perfected to visually reflect the magnitude of their Eigenvector values used to identify the most influential nodes in the network. Edges were also depicted with a stronger intensity in order to reflect Eigenvector values better. As such, calculation of Eigenvector Centrality implies a standardization process (Bonacich & Lloyd, 2001; Freeman, 1979), in which all the actions of all the game complexes contributed to the analysis, thus providing a more precise view of how the variables contribute and influence different levels of effectivity. Therefore, this centrality measure will show the results of the interaction patterns between the variances (Duch, Waitzman, & Amaral, 2010), aiding in determining if the analysed actions influence the effectiveness of the team.

Inter-observer reliability was calculated with the analysis of 10% of the total sample (total of 210 actions) as suggested in the literature (Fleiss, Levin, and Paik (2013)), having presented Cohen's Kappa values above 0.75 for all variables.

Results

The established networks present the Eigenvector values for each level of efficacy (i.e., 0, 1 or 2). The network below (Figure 1) reveals game patterns for Efficacy 0 (Error).

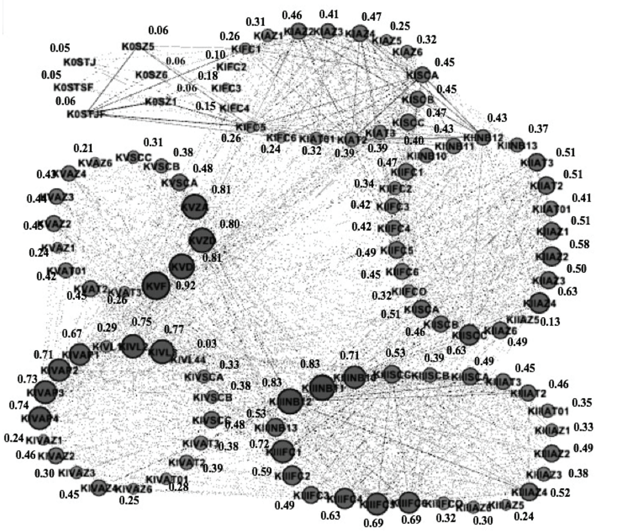

FIGURE 1. Network with Eigenvector Centrality for all variables related to the efficacy 0 in women's volleyball. Terminology: in each node, codes are represented by the name of complex (e.g., KII), followed by the variable and its category (e.g., KIIAZ6 indicates that the action occurred in complex II, the variable in question was Attack Zone, and the category is Zone 6). Codes for the different variables: IPS – Initial Position of the Serve; ST – Serve Type (Jump, Jump-Float and Standing-Float); FC – Zone of First Contact; SC Setting Condition; AZ –Attack Zone; AT – Attack Tempo; BO – Block Opposition; KIVB – Number of Available Player Before of Attack Coverage; KIVL – Number of Coverage Lines; KVD and KVF – Downball and Freeball; KVTZ –Target Zone in KV (Attack or Defence Zone).

Eigenvector values have highlighted for Efficacy 0 (i.e., error; Figure 1): (i) Serve Type Jump Float (0.06) in K0; (ii) Setting Condition C in KI (0.36), KII (0.52), KIII (0.65) and KIV (0.48); Setting Condition A in KV (0.46); (iii) Attack Zones 4 and 2 in KI (0.30 and 0.39), KII (0.41 and 0.43), KIV (0.52 and 0.49), KIV (0.46 and 0.40), and KV (0.31 for both); in KIII, Attack Zone 4 (0.48) was followed by Zone 1 (0.48); (iv) Attack Tempos 2 and 3 in KI (0.39 both), KII (0.51 and 0.51), KIII (0.46 and 0.45), and KIV (0.39 and 0.38); Attack Tempos 2 and 1 in KV (0.45 and 0.41).

The game patterns related to Efficacy 1 (Continuity) is presented in Figure 2.

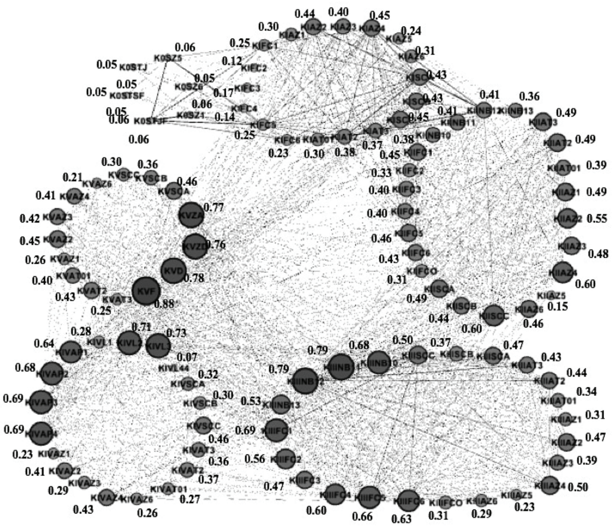

FIGURE 2. Network with Eigenvector Centrality for all variables related to the efficacy 1 in women's volleyball. Terminology: in each node, codes are represented by the name of complex (e.g., KII), followed by the variable and its category (e.g., KIIAZ6 indicates that the action occurred in complex II, the variable in question was Attack Zone, and the category is Zone 6). Codes for the different variables: IPS – Initial Position of the Serve; ST – Serve Type (Jump, Jump-Float and Standing-Float); FC – Zone of First Contact; SC Setting Condition; AZ –Attack Zone; AT – Attack Tempo; BO – Block Opposition; KIVB – Number of Available Player Before of Attack Coverage; KIVL – Number of Coverage Lines; KVD and KVF – Downball and Freeball; KVTZ –Target Zone in KV (Attack or Defence Zone).

Eigenvector values have highlighted for Efficacy 1 (i.e., continuity): (i) Serve Type Jump Float (0.06) in K0; (ii) Setting Condition C in KI (0.45), KII (0.60), KIII (0.50) and KIV (0.46); Setting Condition A in KV (0.46); (iii) Attack Zone 4 in KI (0.45), KII (0.60), KIII (0.50), and KIV (0.43); AZ 2 in KV; (iv) Attack Tempo 2 in KI (0.37), KII (0.49), KIII (0.44), KIV (0.37), and KV (0.43).

The game patterns associated with Efficacy 2 (point) is presented in Figure 3.

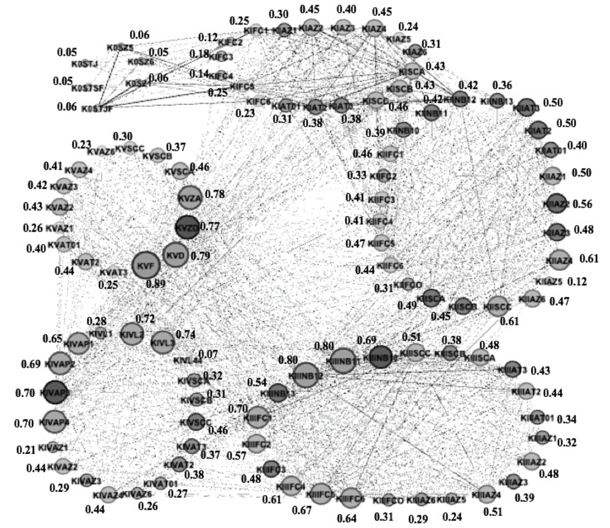

FIGURE 3. Network with Eigenvector Centrality for all variables related to the efficacy 2 in women's volleyball. Terminology: in each node, codes are represented by the name of complex (e.g., KII), followed by the variable and its category (e.g., KIIAZ6 indicates that the action occurred in complex II, the variable in question was Attack Zone, and the category is Zone 6). Codes for the different variables: IPS – Initial Position of the Serve; ST – Serve Type (Jump, Jump-Float and Standing-Float); FC – Zone of First Contact; SC Setting Condition; AZ –Attack Zone; AT – Attack Tempo; BO – Block Opposition; KIVB – Number of Available Player Before of Attack Coverage; KIVL – Number of Coverage Lines; KVD and KVF – Downball and Freeball; KVTZ –Target Zone in KV (Attack or Defence Zone).

Our results further highlighted, for Efficacy 2 (i.e., point): (i) Serve Type Jump Float (0.06) in K0. (ii) Setting Condition C in KI (0.46), KII (0.61), KIII (0.51) and KIV (0.46); SCA in KV (0.48); (iii) Attack Zones 4 and 2 in KI (0.45 and 0.45 re-

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spectively), KII (0.61, 0.56), KIII (0.51, 0.48), KIV (0.44, 0.44); Attack Zone 2 in KV (0.43); (iv) Attack Tempo 3 in KI (0.38), KII (0.50), KIII (0.44), KIV (0.38), and KV (0.44).

Discussion

This study aimed to understand if game patterns impacted the efficacy of each play in high-level women's volleyball. While the mainstream view is that distinct game patterns affect the efficacy level (e.g., Marcelino et al. (2008)), a recent study by the authors of the present paper in high-level men's volleyball showed that game efficacy was independent of game patterns (Laporta et al., 2019). Here, we applied Social Network Analysis with a calculation of Eigenvector Centrality in women's volleyball, considering simultaneously direct and indirect gaming actions connections between the six functional game complexes (e.g., Laporta et al. (2018a, 2018b)) and analysing the three levels of efficacy.

Our results showed that game patterns were highly similar for all three levels of efficacy (i.e., the analysed variables and their relationships presented roughly the same behaviour regardless of efficacy level), as had happened with our study in men's volleyball (Laporta et al., 2019). First and foremost, playing under non-ideal conditions (i.e., Setting Condition C) was a core feature associated with all efficacy levels (E0, 1 and 2) in Complexes I to IV. These findings evidence the need for teams to be capable of playing a large portion of time under non-ideal or off-system conditions, and therefore reinforcing the conclusions of previous studies in women's volleyball (Hurst et al., 2016; Laporta et al., 2018a, 2018b). However, in KV (i.e., freeball, usually representing good conditions for the realization of the first contact) setting occurred most commonly under ideal conditions (i.e., Setting Condition A), but also regardless of efficacy level. These results concur to suggest that individual skill may overcome collective game patterns. Additionally, attacks on the extremities of the net (i.e., Zones 4 and 2) and using slower attack tempos (i.e., Tempos 2 and 3) were central across all efficacy levels, as had occurred in men's volleyball (Laporta et al., 2019).

Notwithstanding, our results differ from those found in men's volleyball in some respects, namely previous studies in men also applying SNA with Eigenvector Centrality (Laporta et al. 2019). In women's top-level, Jump-Float Serve had higher eigenvector values associated with increasing effectivity and also with continuity, which corroborates previous studies, also in women volleyball; however, this serve type is more frequently used and also more effective in women's volleyball than Jump Serve (Hurst et al., 2016; Palao, Manzanares, and Ortega, 2009). In addition, serving from the middle backcourt (i.e., Zone 6) caused lower continuity and scoring values in top-level women's volleyball, unlike what was observed in men's volleyball (Laporta et al., 2019). In men's volleyball, due to the greater use of Jump Serve (service with greater power), the serve performed in Zone 6 does not favour this execution, in which the athlete's trajectories are reduced by the centralized position in the backcourt. However, some authors argue that Serve Zones 1 and 5 are the most frequently used zones, as athletes tend to serve behind the zones that they will subsequently occupy for defence; specifically, there is a decrease in the athlete's displacement, making the arrival in the defence zone faster (Loureiro et al., 2017; Quiroga et al., 2010). In addition, these areas can increase the ball trajectories' distance (diagonal paths) decreasing the error probability and increasing the point probability, wherein the server can use a greater distance to increase the serve intensity, search for conflict zones between two receivers, as well as use vulnerable spaces to hinder the movement of some players.

Women's volleyball has a characteristic of playing with a certain degree of security, augmenting the values of continuity actions and thus increasing the number of actions in the transition phase (KII and KIII) compared to men's volleyball (Costa et al., 2012; Kountouris, Drikos, Aggelonidis, Laios, & Kyprianou, 2015). In this study, the complexes that present less risk and greater security are Complexes I, II and III, and the safe attack zone in which the athletes appear to control the risk is in Attack Zone 4. While Complexes IV and V revealed a tendency to reverse this pattern, with the attack being performed mostly in Zone 2. We note that when this attempt to reverse this pattern occurred in these two rarely occurring complexes, the risk was increased and in less favourable situations (such as in KIV) thus increasing the values associated with continuity and error of the actions. This result may be associated with off-system play (extremities zones and Setting Conditions C) and the opposite player importance in men's volleyball (G. D. C. Costa et al., 2016), while facing easier conditions they attack by riskier zones (e.g., zone 2).

In addition, although men use more power in attack actions, they have tended to play a slower game, with Tempo 3 predominating (Laporta et al., 2018a; Loureiro et al., 2017), women presented a tendency of playing a safer game (Hurst et al., 2016), with more predictable attack zones but intending to increase the unpredictability through of game speed diversity (different Attack Tempos), for which the intermediate attack tempo (AT 2) presented high centrality values in the majority of the game complexes. The data also suggested that women's volleyball seems to present greater predictability with regard to the playing space (Attack Zones) while increasing the risk through the playing speed (Attack Tempo), in comparison with our previous study in men's volleyball (Laporta et al., 2019).

The results further reinforced the notion that, in high-level volleyball's attack, individuals' skills may play a more relevant role than game patterns, at least where play efficacy is considered. Since volleyball does not allow invasion of the opponent's court, the blocker cannot interfere directly with the attacker's action, which might explain this result. Therefore, our results suggest that perhaps the attacker's individual skill and privilege of contacting the ball first might surpass the importance of how the play unfolded up until that moment. If future studies confirm this, it might support the perceptions that high-level setters have concerning the momentum of each attacker during a set or match (Mesquita & Graça, 2002; Queiroga et al., 2005).

Overall, our results support the utilization of SNA and Eigenvector Centrality to understand game patterns and also highlight the importance of individual skill in determining attack efficacy in high-level women's volleyball, since game patterns were extremely similar across all levels of play efficacy. It is further highlighted that women's volleyball is predictable in relation to the playing space, increasing the risk through game speed. Future studies should evaluate how situational constraints impact upon individual actions (e.g., match status, results or previous individual actions by the same player, type of set, home vs away match, among other possibilities). We further recommend that this research is replicated in different competitions and playing levels, to understand whether this represents a strong feature inherent to volleyball or an idiosyncrasy of a few selected samples.

References

Afonso, J., & Mesquita, I. (2011). Determinants of block cohesiveness and attack efficacy in high-level women's volleyball. *European Journal of Sport Science, 11*(1), 69-75.

Bonacich, P., & Lloyd, P. (2001). Eigenvector-like measures of centrality for asymmetric relations. *Social Networks, 23*(3), 191-201.

Costa, G. D. C., Ceccato, J. S., de Oliveira, A. S., de Britto Evangelista, B. F., de Oliveira Castro, H., & Ugrinowitsch, H. (2016). Men's Volleyball Height Level: Association between Game Actions on the Side-Out |Voleibol Masculino de Alto Nível: associação entre as ações de jogo no side-out|. *Journal of Physical Education, 27*(1).

Costa, G., Afonso, J., Brant, E., & Mesquita, I. (2012). Differences in game patterns between male and female youth volleyball. *Kinesiology, 44*(1), 60-66.

Cotta, C., Mora, A. M., Merelo, J. J., & Merelo-Molina, C. (2013). A network analysis of the 2010 FIFA world cup champion team play. *Journal of Systems Science and Complexity, 26*(1), 21-42.

Duch, J., Waitzman, J. S., & Amaral, L. A. N. (2010). Quantifying the Performance of Individual Players in a Team Activity. *PLoS ONE, 5*(6), e10937. doi:10.1371/journal.pone.0010937

Fleiss, J. L., Levin, B., & Paik, M. C. (2013). *Statistical methods for rates and proportions*: John Wiley & Sons.

Freeman, L. C. (1979). Centrality in social networks conceptual clarification. *Social Networks, 1*(3), 215-239.

Hurst, M., Loureiro, M., Valongo, B., Laporta, L., Nikolaidis, P. T., & Afonso, J. (2016). Systemic Mapping of High-Level Women's Volleyball using Social Network Analysis: The Case of Serve (K0), Side-out (KI), Side-out Transition (KII) and Transition (KIII). *International Journal of Performance Analysis in Sport, 16*(2).

Kountouris, P., Drikos, S., Aggelonidis, I., Laios, A., & Kyprianou, M. (2015). Evidence for Differences in Men's and Women's Volleyball Games Based on Skills Effectiveness in Four Consecutive Olympic Tournaments. *Comprehensive Psychology, 4*, 30.50. CP. 34.39.

Laporta, L., Afonso, J., & Mesquita, I. (2018a). Interaction network analysis of the six game complexes in high-level volleyball through the use of Eigenvector Centrality. *PLoS ONE, 13*(9), e0203348. doi: 10.1371/journal.pone.0203348

Laporta, L., Afonso, J., & Mesquita, I. (2018b). The need for weighting indirect connections between game variables: Social Network Analysis and eigenvector centrality applied to high-level men's volleyball. *International Journal of Performance Analysis in Sport, 18*(6), 1067-1077. doi: 10.1080/24748668.2018.1553094

Laporta, L., Afonso, J., Valongo, B., & Mesquita, I. (2019). Using social network analysis to assess play efficacy according to game patterns: a game-centred approach in high-level men's volleyball. *International Journal of Performance Analysis in Sport, 19*(5), 866-877. doi: 10.1080/24748668.2019.1669007

Laporta, L., Nikolaidis, P., Thomas, L., & Afonso, J. (2015). The Importance of Loosely Systematized Game Phases in Sports: The Case of Attack Coverage Systems in High-Level Women's Volleyball. *Montenegrin Journal of Sports Science and Medicine, 4*(1), 19-24.

Loureiro, M., Hurst, M., Valongo, B., Nikolaidis, P., Laporta, L., & Afonso, J. (2017). A Comprehensive Mapping of High-Level Men's Volleyball Gameplay through Social Network Analysis: Analysing Serve, Side-Out, Side-Out Transition and Transition. *Montenegrin Journal of Sports Science and Medicine, 6*(2), 35-41.

Marcelino, R., Mesquita, I., & Afonso, J. (2008). The weight of terminal actions in volleyball. Contributions of the spike, serve and block for the teams' rankings in the World League 2005. *International Journal of Performance Analysis in Sport, 8*(2), 1-7.

Marcelino, R., Sampaio, J., & Mesquita, I. (2011). Investigação centrada na análise do jogo: da modelação estática à modelação dinâmica.[Research on the game analysis: from static to dynamic modeling]. *Revista Portuguesa de Ciências do Desporto, 11*(1), 481-499.

Mesquita, I., & Graça, A. (2002). Probing the strategic knowledge of an elite volleyball setter: a case study. *International Journal of Volleyball Research, 5*(1), 13-17.

Mesquita, I., Palao, J. M., Marcelino, J., & Afonso, J. (2013). *Performance Analysis in indoor volleyball and beach volleyball* (T. McGarry, P. O'Donoghue, & J. Sampaio Eds.). Oxon: Routledge.

O'Donoghue, P. (2009). *Research methods for sports performance analysis*. New York: Routledge.

Palao, J. M., Manzanares, P., & Ortega, E. (2009). Techniques used and efficacy of volleyball skills in relation to gender. *International Journal of Performance Analysis in Sport, 9*(2), 281-293.

Queiroga, M., Matias, C., Greco, P., Graça, A., & Mesquita, I. (2005). The dimension of the high-level setter's tactical strategic knowledge: Study with setters of Brazilian national teams. *Brazilian Journal of Physical Education, Special Edition*, 111-119.

Quiroga, M. E., García-Manso, J. M., Rodríguez-Ruiz, D., Sarmiento, S., De Saa, Y., & Moreno, M. P. (2010). Relation between in-game role and service characteristics in elite women's volleyball. *The Journal of Strength & Conditioning Research, 24*(9), 2316-2321.

Silva, M., Marcelino, R., Lacerda, D., & João, P. V. (2016). Match Analysis in Volleyball: a systematic review. *Montenegrin Journal of Sports Science and Medicine, 5*(1), 35-46.

Wäsche, H., Dickson, G., Woll, A., & Brandes, U. (2017). Social network analysis in sport research: an emerging paradigm. *European Journal for Sport and Society, 14*(2), 138-165.

Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications* (Vol. 8). Cambridge University Press.

Yamamoto, Y., & Yokoyama, K. (2011). Common and unique network dynamics in football games. *PLoS ONE, 6*(12), e29638.

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ORIGINAL SCIENTIFIC PAPER

Peak External Intensity Decreases across Quarters during Basketball Games

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Abstract

The purpose of this study was to compare peak external intensities across game quarters in basketball. Eight semi-professional male players were monitored using accelerometers. For all quarters, peak intensities were determined via moving averages for PlayerLoad/minute (PL·min-1) using sample durations of 15 s, 30 s, 1 min, 2 min, 3 min, 4 min, and 5 min. Linear mixed models and effect sizes (ES) were used to compare peak intensities between quarters for each sample duration. Small decreases in peak PL·min-1 occurred between Quarters 1 and 4 for all sample durations (ES = 0.21-0.49). Small decreases in peak PL·min-1 were apparent between quarters 1 and 2 for 30-s, 1-min, and 3-min sample durations (ES = 0.24-0.33), and between quarters 3 and 4 for 2-5-min sample durations (ES = 0.20-0.24). Peak intensities decline across quarters with game progression in basketball, providing useful insight for practitioners to develop game-specific training and tactical strategies.

Keywords: *accelerometer, microsensor, training prescription, worst-case scenario*

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Introduction

In basketball, players are exposed to intense physical demands during games. Specifically, games involve frequent multi-directional movements (Taylor et al., 2017) along with substantial running demands (Stojanović et al., 2018). Given the physically demanding nature of basketball, optimal preparation leading into games is of critical importance to ensure that players can withstand the demands faced, consequently increasing the likelihood of successful performance (Fox et al., 2019).

Quantifying player demands across the entire game as well as during game quarters (Garcia et al., 2020) is essential to provide reference workloads and identify performance deficits across games, which in turn can be used to inform training prescription. In considering the demands encountered by players, data are typically expressed as either external demands or internal responses. Specifically, external demands represent the training or game stimuli imposed on players, while internal responses relate to the psychological and physiological reactions of players to the imposed demands (Impellizzeri et al., 2019). With respect to training prescription, the external demands represent the activity dosage directly prescribed and

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controlled by practitioners to bring about the desired responses and subsequent adaptations from players (Fox et al., 2019). In turn, it is essential to quantify the external demands experienced during games for training demands to prepare players for competitive scenarios effectively. In professional basketball players, external demands (total distance and player load) have been shown decrease (effect size (ES) = 1.27–1.31, large) between Quarter 1 and 4 (Garcia et al., 2020). In addition, external demands (high-intensity activity and PlayerLoad, respectively) have been shown to decrease across Quarter 3 and 4 (ES = 1.4–3.2, large-very large) (Scanlan et al., 2015), as well as overtime periods (ES = 1.46, large) (Scanlan et al., 2019), compared Quarters 1 and 2 during games in semi-professional players. Consequently, existing data suggest external demands decrease across games, likely as a function of changes in tactical approaches, and accumulated fatigue.

While understanding differences in external demands between game quarters is essential to prescribe training for basketball players more precisely, previous work has quantified total external load or average intensity across each quarter (Garcia et al., 2020; Scanlan et al., 2019). However, in better understanding the game demands experienced by players, the quantification of peak external intensities may provide further insights by determining the most demanding passages of game-play, also referred in the existing literature as “worst-case scenarios” (Cunningham et al., 2018). Specifically, understanding fluctuations in peak intensities between quarters may indicate player ability to sustain high-intensity activity across games for greater precision in prescribing training and managing fatigue-related outcomes. It is currently not clear whether trends reported in external demands across quarters are also apparent for metrics representing the most demanding passages of games. To date, no research has compared peak external intensities across game quarters in basketball, with only peak external intensities captured during entire games previously examined (Fox et al., 2020; Salazar & Castellano, 2019). Therefore, the purpose of this study was to compare peak external intensities encountered by players across game quarters in basketball.

Methods

Eight semi-professional, male basketball players (age: 23 ± 4 yr; stature: 191 ± 8 cm; body mass: 87 ± 16 kg; semi-professional playing experience: 5 ± 2 yr) volunteered to participate in the study. All players belonged to the same team competing in the Queensland Basketball League, a second-tier, state-level Australian basketball team. Other players from the same team received limited playing time across the season (<4 min per game) and therefore were not included in the study. Prior to study commencement, players were screened for injuries or health conditions that may have prevented safe participation. All players were informed of the purpose of the study and any potential risks or benefits of participation before providing voluntary written informed consent prior to participating. All procedures were approved by an institutional Human Research Ethics Committee.

Across the season, 18 games were scheduled, with 1-3 games held each week between Friday and Sunday. Each game consisted of 4 × 10-min quarters, with 2- and 15-min breaks between quarters and halves, respectively. Prior to study commencement, anthropometric data were collected on each player including stature using a portable stadiometer (Seca 213, Seca GMBH, Hamburg, Germany) and body mass using electronic scales (BWB-600, Tanita Corporation, Tokyo, Japan). For all games, players were fitted with microsensor units (OptimEye s5, Catapult Innovations, Melbourne, Australia) mounted at the upper torso, between the scapulae, in neoprene vests (Catapult Innovations, Melbourne, Australia). To reduce any potential between-device variability, players wore the same microsensor unit for each game across the season (Fox et al., 2019). External demands were measured via the 100-Hz accelerometer, housed within the microsensor unit, and exported as raw instantaneous PlayerLoad™ (PL) via proprietary software (OpenField version 8, Catapult Innovations, Melbourne, Australia). PL is the proprietary metric of the microsensor, which represents the square root of the change in acceleration across the transverse (x), coronal (y), and sagittal (z) planes (Montgomery et al., 2010). The reliability of PL has been previously supported in team sport athletes (Luteberget et al., 2017).

Raw PL data were then exported and processed in RStudio (version 3.5.3) using the “zoo” package. Moving averages were calculated for PL across consecutive samples spanning 15 s, 30 s, 1 min, 2 min, 3 min, 4 min, and 5 min. For each game, the highest intensity obtained by each player in each quarter for each sample duration was determined. Peak intensity was expressed as PL·min^{-1} by determining accumulated PL (sum of the raw PL across each duration), divided by 100, to represent the typical scaling factor applied (Montgomery et al., 2010). For each sample duration, PL was then reported relative to 1 min (e.g., the 15-s sample duration was multiplied by 4 to convert to PL·min^{-1}, and the 5 min sample duration was divided by 5 to convert to PL·min^{-1} (Fox et al., 2020)).

Peak PL·min^{-1} in each quarter for each sample duration is reported as mean ± standard deviation (SD). The normality of data distribution and sphericity were confirmed using the Shapiro-Wilk statistic and Levene’s Test for equality of variances. For each sample duration, peak intensities in each game quarter were compared using linear mixed models with Bonferroni post hoc tests. The game quarter was entered as the fixed factor (4 levels), while the player (n = 8) was entered as the random term (Peugh, 2010). Effect sizes (Cohen’s d) with 95% confidence intervals were computed for all pairwise comparisons to identify the magnitude of differences between game quarters. Magnitudes were interpreted as trivial: >0.20, small: 0.20–0.59, moderate: 0.60–1.19, large: 1.20–1.99, and very large: ≥2.00 (Hopkins, 2006). Where confidence intervals for effect sizes crossed ±0.2, the effect was interpreted as unclear (Hopkins et al., 2009). Linear mixed models and post-hoc tests were conducted using SPSS (Version 26, IBM Corporation, Armonk, USA) while effect sizes and confidence intervals were calculated using a customised Microsoft Excel spreadsheet (Version 15, Microsoft Corporation, Redmond, USA). Statistical significance was accepted where $p < 0.05$.

Results

Peak PL·min^{-1} across game quarters for each sample duration are presented in Figure 1. Pairwise comparisons in peak PL·min^{-1} between quarters for each sample duration are presented in Table 1. For the 15-s, 1-min, 2-min, 4-min, and 5-min sample durations, differences in peak PL·min^{-1} between game quarters were non-significant, and effect sizes were trivial-small in magnitude ($p > 0.05$). For the 30-s sample duration, differences in peak PL·min^{-1} between game quarters were

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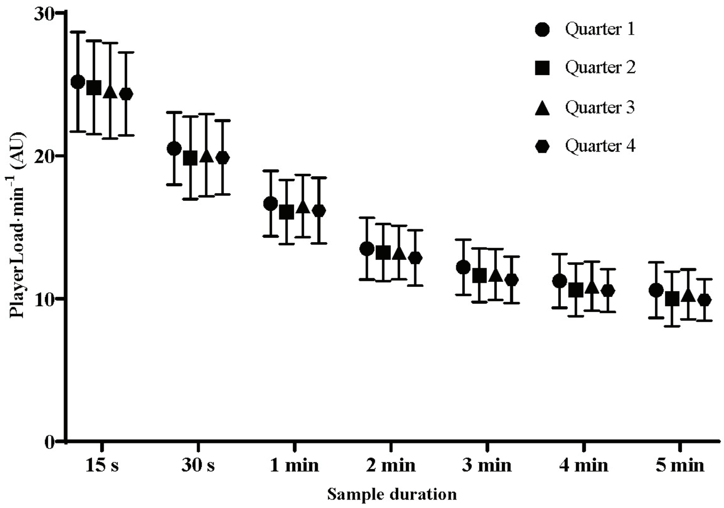

FIGURE 1. Peak intensity across basketball game quarters

non-significant, and effect sizes were unclear-small in magnitude ($p > 0.05$). For the 3-min sample duration, there was a significant decline in peak $PL·min^{-1}$ between Quarter 1 and Quarter 4 ($p = 0.007$, small), with all other differences in peak $PL·min^{-1}$ between quarters being non-significant and trivial-small in magnitude ($p > 0.05$).

Table 1. Pairwise comparisons in peak PlayerLoad per minute between game quarters for each sample duration in semi-professional, male basketball players.

Sample duration comparisons	*Effect size*	95% CI	*P*
15-s sample			
Quarter 1 vs Quarter 2	0.12	-0.12, 0.36	1.0
Quarter 1 vs Quarter 3	0.18	-0.06, 0.43	1.0
Quarter 1 vs Quarter 4	0.26*	0.01, 0.51	0.52
Quarter 2 vs Quarter 3	0.07	-0.18, 0.32	1.0
Quarter 2 vs Quarter 4	0.14	-0.11, 0.39	1.0
Quarter 3 vs Quarter 4	0.07	-0.19, 0.32	1.0
30-s sample			
Quarter 1 vs Quarter 2	0.24*	0.01, 0.48	0.56
Quarter 1 vs Quarter 3	0.17	-0.07, 0.42	1.0
Quarter 1 vs Quarter 4	0.25*	0.01, 0.49	0.73
Quarter 2 vs Quarter 3	-0.07	-0.31, 0.18	1.0
Quarter 2 vs Quarter 4	-0.01	-0.26, 0.24	1.0
Quarter 3 vs Quarter 4	0.06	-0.20, 0.31	1.0
1-min sample			
Quarter 1 vs Quarter 2	0.26*	0.02, 0.50	0.44
Quarter 1 vs Quarter 3	0.08	-0.16, 0.32	1.0
Quarter 1 vs Quarter 4	0.21*	-0.03, 0.46	0.90
Quarter 2 vs Quarter 3	-0.19	-0.43, 0.06	1.0
Quarter 2 vs Quarter 4	-0.04	-0.29, 0.21	1.0
Quarter 3 vs Quarter 4	0.14	-0.12, 0.39	1.0
2-min sample			
Quarter 1 vs Quarter 2	0.13	-0.11, 0.37	1.0
Quarter 1 vs Quarter 3	0.13	-0.11, 0.37	1.0
Quarter 1 vs Quarter 4	0.31*	0.07, 0.56	0.19
Quarter 2 vs Quarter 3	0.01	-0.25, 0.25	1.0
Quarter 2 vs Quarter 4	0.19	-0.06, 0.44	1.0
Quarter 3 vs Quarter 4	0.20*	-0.06, 0.45	1.0

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Sample duration comparisons	*Effect size*	95% CI	*P*
3-min sample			
Quarter 1 vs Quarter 2	0.30*	0.03, 0.54	0.18
Quarter 1 vs Quarter 3	0.27*	0.02, 0.51	0.37
Quarter 1 vs Quarter 4	0.49*	0.24, 0.74	**0.007**
Quarter 2 vs Quarter 3	-0.04	-0.28, 0.21	1.0
Quarter 2 vs Quarter 4	0.18	-0.07, 0.43	1.0
Quarter 3 vs Quarter 4	0.22*	-0.03, 0.48	1.0
4-min sample			
Quarter 1 vs Quarter 2	0.33*	0.09, 0.57	0.095
Quarter 1 vs Quarter 3	0.20*	-0.04, 0.44	1.0
Quarter 1 vs Quarter 4	0.40*	0.15, 0.64	0.057
Quarter 2 vs Quarter 3	-0.15	-0.39, 0.10	1.0
Quarter 2 vs Quarter 4	0.04	-0.21, 0.29	1.0
Quarter 3 vs Quarter 4	0.20*	-0.06, 0.45	1.0
5-min sample			
Quarter 1 vs Quarter 2	0.31*	0.07, 0.55	0.134
Quarter 1 vs Quarter 3	0.16	-0.09, 0.40	1.0
Quarter 1 vs Quarter 4	0.39*	0.14, 0.64	0.068
Quarter 2 vs Quarter 3	-0.04	-0.29, 0.20	1.0
Quarter 2 vs Quarter 4	0.05	-0.20, 0.30	1.0
Quarter 3 vs Quarter 4	0.24*	-0.01, 0.50	0.944

Note. CI = Confidence Interval, Bolded P value indicates significant (P <0.05) difference, * Indicates small effect size (0.20-0.59).

Discussion

The present study is the first to compare peak external intensities encountered across game quarters in semi-professional basketball. Our data revealed that for all sample durations assessed, there was a small decrease in peak intensity encountered between the first and fourth quarters. In addition, for all sample durations, except 15 s and 2 min, small declines in peak intensities were apparent between the first and second quarters. Our data also revealed small declines in peak intensity between the third and fourth quarters (2-, 3-, 4-, and 5-min sample durations) and first and third quarters (3- and 4-min sample durations).

In combination, our findings suggest that decreases in peak external intensities are evident across basketball games, with differences most prominent between the first and fourth quarters given this trend was revealed for all sample durations. Our findings also suggest that over longer sample durations (≥3 min), peak intensity decreases from the first to second and third to fourth quarters. Differences in peak PL·min-1 across games may be related to fatigue-related mechanisms with past research suggesting that factors such as glycogen depletion and muscle damage contribute to decreases in external demands across basketball games (Scanlan et al., 2015). These fatigue-related mechanisms may also explain why small differences in peak external intensities across all sample durations were obtained between the first and fourth quarters, whereas small differences in peak external intensity were obtained between the first and second quarters and between the third and fourth quarters only over longer sample durations. Given that exercise intensity is mediated by duration, player's maximal effort likely cannot be maintained at the same intensity for extended periods, which explains why small decreases in intensity were apparent within the same game half, over longer sample durations. In this regard, the break between halves allows for greater recovery opportunity (15 min) compared to between quarters (2 min), likely explaining the lack of any clear differences in peak PL·min^{-1} between the second and third quarters. In addition, longer sample durations likely include periods of inactivity or low-intensity activity (e.g., substitutions, time-outs, and stoppages in play for a change in possession of free-throw) which will also contribute to the lower intensities achieved. Lastly, the decline in peak intensities across games may also be related to tactical strategies, whereby game pace is reduced in later quarters to gain more ball control when in possession to increase the likelihood of successful game outcomes (Abdelkrim et al., 2007).

In interpreting the findings of the present study, some notable limitations should be considered. Data were collected on a semi-professional, male basketball team, so it cannot be assumed that the peak external intensities and differences in intensities observed between quarters are representative of female players (Scanlan et al., 2012) or players participating in other leagues or at other playing levels (Scanlan et al., 2011), suggesting that future work is needed to establish peak intensities encountered across various playing levels. In addition, only a single measure of intensity was assessed due to the frequent use of PL in basketball; however, when assessing game demands to optimize training prescription, other measures of intensity should also be explored.

Data from the present study suggest that peak external intensities decline across basketball games, with the most notable declines in intensity occurring between the first and fourth quarters. In addition, over longer sample durations (≥

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3 min) peak external intensity decreased within each half (i.e., between Quarters 1 and 2 and between Quarters 3 and 4). Therefore, basketball practitioners should assess not only total external demands or average external intensity across game quarters, but should also consider the most intense periods of activity encountered across different sample durations to assist in guiding training prescription. In this regard, using reference peak external intensity values from the first quarter may be useful, given these data represent the highest external intensities reached across the entire game. Specifically, preparing players to be able to maintain external intensities encountered in the first quarter during later game periods may assist in managing player fatigue and promoting optimal preparation for games. In further optimizing training prescription, attention should also be given to data captured over sample durations ≥3 min as these longer durations appear to provide further insights regarding fluctuations in peak external demands encountered within each game half.

References

Abdelkrim, N. B., El Fazaa, S., & El Ati, J. (2007). Time–motion analysis and physiological data of elite under-19-year-old basketball players during competition. *British Journal of Sports Medicine, 41*(2), 69-75. doi: 10.1136/bjsm.2006.032318

Cunningham, D. J., Shearer, D. A., Carter, N., Drawer, S., Pollard, B., Bennett, M., Eager, R., Cook, C. J., Farrell, J., Russell, M., & Kilduff, L. P. (2018). Assessing worst case scenarios in movement demands derived from global positioning systems during international rugby union matches: Rolling averages versus fixed length epochs. *PLoS One, 13*(4). doi: 10.1371/journal.pone.0195197

Fox, J., Conte, D., Stanton, R., McLean, B., & Scanlan, A. (2020). The application of accelerometer-derived moving averages to quantify peak demands in basketball: A comparison of sample duration, playing role, and session type. *Journal of Strength and Conditioning Research*. In press. doi: 10.1519/JSC.0000000000003486

Fox, J., O'Grady, C. J., & Scanlan, A. T. (2019). The relationships between external and internal workload during basketball training and competition. *International journal of sports physiology and performance*. In press.

Garcia, F., Vázquez-Guerrero, J., Castellano, J., Casals, M., & Schelling, X. (2020). Differences in physical demands between game quarters and playing positions on professional basketball players during official competition. *Journal of Sports Science & Medicine, 19*, 256-263.

Hopkins, W. A. (2006). A scale of magnitudes for Effect Statistics. *SportSci.* Retrieved from http://www.sportsci.org/resource/stats/index.html

Hopkins, W., Marshall, S., Batterham, A., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and science in sports and exercise, 41*(1), 3-12. doi: 10.1249/MSS.0b013e31818cb278

Impellizzeri, F. M., Marcora, S. M., & Coutts, A. J. (2019). Internal and external training load: 15 years on. *International Journal of Sports Physiology and Performance, 14*(2), 270-273. doi: 10.1123/ijspp.2018-0935

Luteberget, L. S., Holme, B. R., & Spencer, M. (2017). Reliability of wearable inertial measurement units to measure physical activity in team handball. *International Journal of Sports Physiology and Performance, 13*(4), 467-473. doi: 10.1123/ijspp.2017-0036

Montgomery, P. G., Pyne, D. B., & Minahan, C. L. (2010). The physical and physiological demands of basketball training and competition. *International Journal of Sports Physiology and Performance, 5*(1), 75-86. doi: 10.1123/ijspp.5.1.75

Peugh, J. L. (2010). A practical guide to multilevel modeling. *Journal of School Psychology, 48*(1), 85-112. doi: 10.1016/j.jsp.2009.09.002

Salazar, H., & Castellano, J. (2019). Most demanding passages in Basketball: A preliminary study. *Sport Performance & Science Reports, 70*(1). Retrieved from: https://sportperfsci.com/wp-content/uploads/2019/08/SPSR73_Salazar_190807_final.pdf

Scanlan, A. T., Dascombe, B. J., Reaburn, P., & Dalbo, V. J. (2012). The physiological and activity demands experienced by Australian female basketball players during competition. *Journal of Science and Medicine in Sport, 15*(4), 341-347. doi: 10.1016/j.jsams.2011.12.008

Scanlan, A. T., Stanton, R., Sargent, C., O'Grady, C., Lastella, M., & Fox, J. L. (2019). Working overtime: The effects of overtime periods on game demands in basketball players. *International Journal of Sports Physiology and Performance, 14*(10), 1331-1337. doi: 10.1123/ijspp.2018-0906

Scanlan, A. T., Tucker, P. S., Dascombe, B. J., Berkelmans, D. M., Hiskens, M. I., & Dalbo, V. J. (2015). Fluctuations in activity demands across game quarters in professional and semi-professional male basketball. *29*(11), 3006-3015. doi: 10.1519/JSC.0000000000000967

Scanlan, A., Dascombe, B., & Reaburn, P. (2011). A comparison of the activity demands of elite and sub-elite Australian men's basketball competition. *Journal of sports sciences, 29*(11), 1153-1160. doi: 10.1080/02640414.2011.582509

Stojanović, E., Stojiljković, N., Scanlan, A. T., Dalbo, V. J., Berkelmans, D. M., & Milanović, Z. (2018). The activity demands and physiological responses encountered during basketball match-play: A systematic review. *Sports Medicine, 48*(1), 111-135. doi: 10.1007/s40279-017-0794-z

Taylor, J. B., Wright, A. A., Dischiavi, S. L., Townsend, M. A., & Marmon, A. R. (2017). Activity demands during multi-directional team sports: A systematic review. *Sports Medicine, 47*(12), 2533-2551. doi: 10.1007/s40279-017-0772-5

ORIGINAL SCIENTIFIC PAPER

Investigation of the Head's Dynamic Response to Boxing Punch Using Computer Simulation

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Abstract

Head injuries are dangerous injuries that are common in combat sports. Nevertheless, the mechanisms of concussion in sport have are not precisely known. Thus, this study aimed to investigate the dynamic response of the head based on linear and rotational accelerations in boxing using computer simulation. The ADAMS software model was used to determine the linear and rotational acceleration of boxing's straight punch. The peak linear acceleration, average linear acceleration, peak rotational acceleration, and average rotational acceleration resulted from the straight punch to head were obtained: 75 g, 20 g, 4036 rad/s^2, 1140 rad/s^2, respectively; the impact times were 30 ms and 3 ms, respectively. The comparison of acceleration tolerance thresholds of head injury and obtained results of this study showed the rotational acceleration only leads to head injury. Furthermore, it is biomechanically improbable that the head would be moved only translationally or rotationally as a result of a straight punch. Therefore, both rotational and linear accelerations should be observed together for future studies.

Keywords: *punch, linear acceleration, rotational acceleration, dynamic response*

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Introduction

Brain damage due to a blow to the head is a serious and significant social and public health problem and has attracted the attention of many researchers in recent years (Chen, 2012). Such injuries may occur in some cases without any apparent brain damage, but they may lead to severe cerebral injury, unconsciousness and death (Wu et al., 2019). The athletes in combat sports, such as boxing, karate, and taekwondo, are exposed to significant forces to the head induced by repeated and targeted blows. Superficial brain injuries due to blows are very common in these sports (Schmitt, Niederer, Cronin, Muser, & Walz, 2014; Walilko, Viano, & Bir, 2005). Most brain injuries and traumas occur due to direct and repeated blows from near distances to the head in martial arts competitions, although these repeated blows may seemingly have no primary symptoms (Hoshizaki, Post, Oeur, & Brien, 2014; Viano et al., 2005). The straight punch to the head is one cause of injuries in boxing (Viano et al., 2005).

Most of the previous studies have investigated the blow to the head and the biomechanics of injuries, focusing on concussions due to traffic accidents or incidents in sports, such as football, but few studies have dealt with concussions due to di-

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rect punches to head and repeated blows for obtaining points in martial arts competitions (Beaudouin, Aus der Fünten, Tröß, Reinsberger, & Meyer, 2019, 2020; Putukian et al., 2019; Rowson, Brolinson, Goforth, Dietter, & Duma, 2009). Viano et al. studied the punch force of eleven Olympic boxers with a 3D model; they investigated not only the direct punch but also the hook and uppercut blows and came to the conclusion that punches cause fewer injuries because of the short time of accelerating; therefore, they do not meet the criterion for brain damage (Viano et al., 2005). Zong et al. presented a 3D finite element model of the human head to assess the possibility of head injury due to the applied blows; the high possibility of spinal cord injury as a result of the wave propagation of stress inside the head was suggested (Zong, Lee, & Lu, 2006). While these studies have provided insight into the mechanisms of head injury, the exact mechanism of head injury has not yet been determined.

Primary investigations show that the key factors were changes in intracranial pressure and skull deformation by using impact forces and cadaver heads. Denny-Brown Russell proposed that head rotation and movement can be noticeable factors (Denny-Brown & Russell, 1941). It has nevertheless not been fully elucidated how outside forces are transmitted internally, nor is it precisely understood what the underlying injury of it is. At present, there are two main mechanisms of head injury: linear and rotational accelerations (Kis et al., 2013; Rowson et al., 2009). Linear acceleration produces focal brain damage, while rotational acceleration generates focal and diffuse brain injuries (Schmitt et al., 2019).

The applied impact forces to the head can lead to various reactions and injuries to the head and neck, depending on the intensity, complexity, location, and direction of the forces. These injuries can target a wide range of layers (e.g., skin, bone, brain layers, brain vessels) and structures (e.g., the eyes, nose, ears, and mouth). Various methods are used to study these effects on the human body (Motherway, Doorly, Curtis, & Gilchrist, 2009; Zong et al., 2006). Among these, computer simulations have made significant contributions to medical, engineering, and sports science.

Despite using headgear in combat sports, concerns over repetitive blows to the head, which may cause considerable cognitive impairments, have increased. Investigating and understanding the mechanism of traumatic injuries to the human head and brain damage is one of the most critical issues of biomechanical studies of head injuries. The effects of forces applied to the head, which appear as accelerations in the head, are important factors in measuring injury. These effects can be measured using simulation methods, but they have been largely ignored in previous studies. They have focused on the wave propagation of stress inside the head. Therefore, this field is a novel topic that is examined in the present study. It can reduce medical costs and prevent head injuries. Therefore, due to the importance of linear acceleration and rotational acceleration parameters in investigating the biomechanics of head injury and the ambiguity of its effect on martial arts, such as boxing, as well as the safety of simulation methods compared to laboratory methods, the current study aims to examine the dynamic response of the head to the boxing punch using computer simulation.

Methods

In this study, at first, an appropriate model of the punch, head, and neck provided by simulation in Mechanical Dynamics Incorporation (MSC) Automated Dynamic Analysis of Mechanical Systems (ADAMS) software (MSC Software Corporation, 2013 version). Head properties such as stiffness, material, the properties of a hit (i.e., modulus of elasticity of skin and skull), damping factor in the impact and other parameters are variables related to contact.

Modelling of the neck with the accurate representations of the features of the human neck and body was an essential part of the simulation. Due to the connection of the head to the neck and body after the force is applied, angular acceleration is created on the head, and the behaviour of the neck is exemplified. Hence, based on the realistic response of the human body to the impact, an appropriate model of the neck with the required and optimum length and stiffness was obtained. In this model, the characteristics and behaviour of the neck and body are simulated by a clamped-free beam. Neck properties included equivalent flexibility, damping coefficient and equiv-

Table 1. Physical and Mechanical Parameters of Simulated Organs

Body Part	Parameter	Amount of Parameter
Neck and Body	Equivalent Length	30 cm
	Equivalent Material	Steel
	Equivalent Diameter	1 cm
Head	Diameter	25 cm
	Stiffness	200 N/m
	Damping Coefficient	12
	Penetration Depth in Impact	4 cm
	Mass	5 kg
Punch	Hand Velocity	6.7 m/s
	Effective Mass	4.4 kg
	Shoulder Backward for Impact	5cm
	The Stiffness Coefficient of Equivalent Linear Spring in Shoulder Joint	30 N/m
	The Equivalent Damping Coefficient in Shoulder Joint	4 N.S/m
	Pre-Loading Force	1500 N
	Force of Punch	4236 N

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alent length. The mechanical properties of the head and neck were adapted from a previous study (Boroushak, Eslami, Kazemi, Daneshmandy, & Johnson, 2018).

Furthermore, the features of punch for modelling were adopted from the study of Walilko et al. (Walilko et al., 2005). After determining the mechanical properties of the system components (Table 1), the motion constraints of the set were created. The hand moves along the shoulder using a linear spring with a stiffness of k. This design was used based on the experimental methods in previous studies (Oeur, 2012). After determining the desired model, a direct punch was applied to the lateral of the head in simulation conditions, because most of the blows to the head in martial arts are applied in the lateral direction of the head. The resulting dynamic response (linear and rotational acceleration) was obtained. Finally, the results were compared with head injury thresholds.

Results

Figure 1 illustrates that straight punch to head in boxing with an impact force of 4236 N produces a mean and peak of linear acceleration of 20 g and 75 g, respectively. Figure 2 shows that the average and peak of rotational accelerations of the head caused by a straight punch was 1140 rad/s² and 4036 rad/s², respectively. The impact duration was specified as 30 ms in the acceleration-time curve. By comparing the linear acceleration curves with the threshold tolerance curve of the head, it can be stated that the created acceleration will be located below the linear acceleration threshold (Figure 3). Also, a comparison of the rotational acceleration-time curve of the current study to the rotational acceleration threshold values of the head (Ommaya, Goldsmith, & Thibault, 2002) concluded that the values obtained were within the head injury threshold.

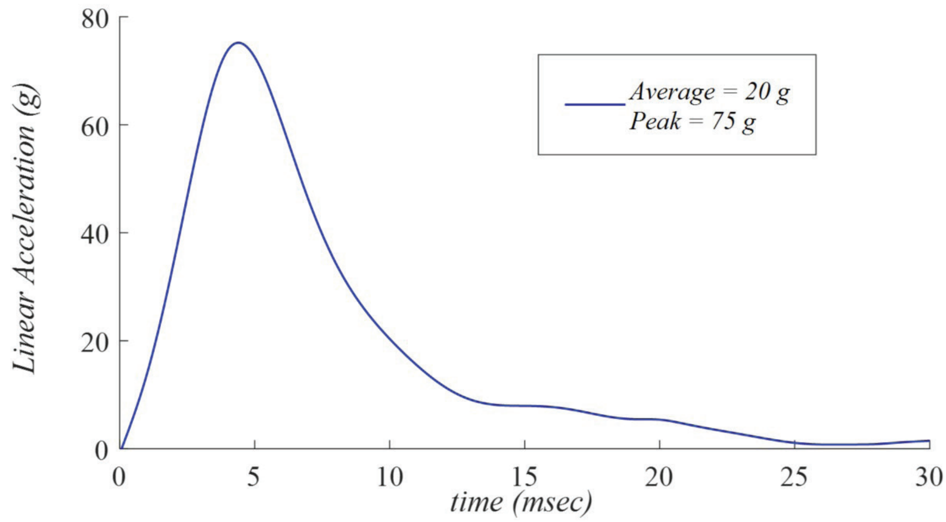

FIGURE 1. Head Linear Acceleration vs Time. G= 9.8 m/s²

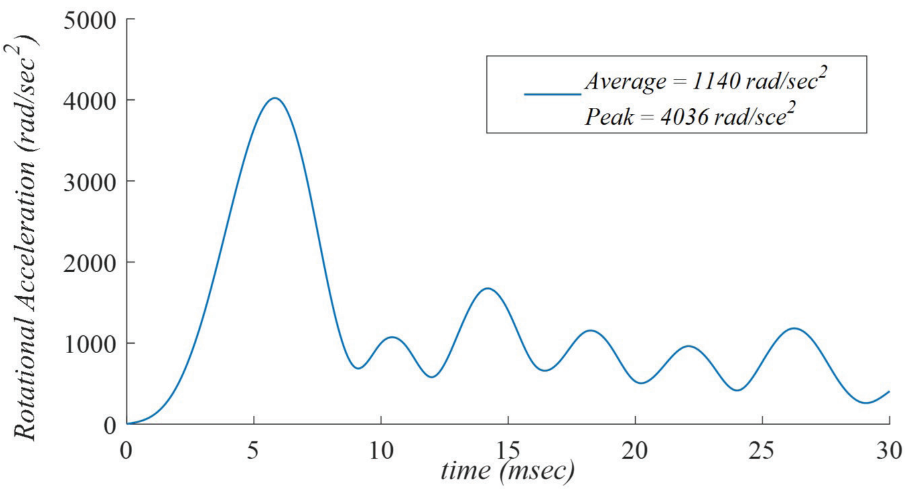

FIGURE 2. Head Rotational Acceleration vs Time

Discussion

The present study simulated the straight punch by using MSC ADAMS software and evaluated the linear and rotational acceleration responses on the head.

The Wayne State University Cerebral Concussion Tolerance Curve (WSTC) was established as a result of extensive cadaver assessments which focus on head acceleration; it shows a relationship between the duration and the mean of anterior-posterior translational acceleration magnitude that drives from similar head damage severity in head contact impacts. When this combination lies above the curve, it exceeds human tolerance, meaning that it makes extreme and

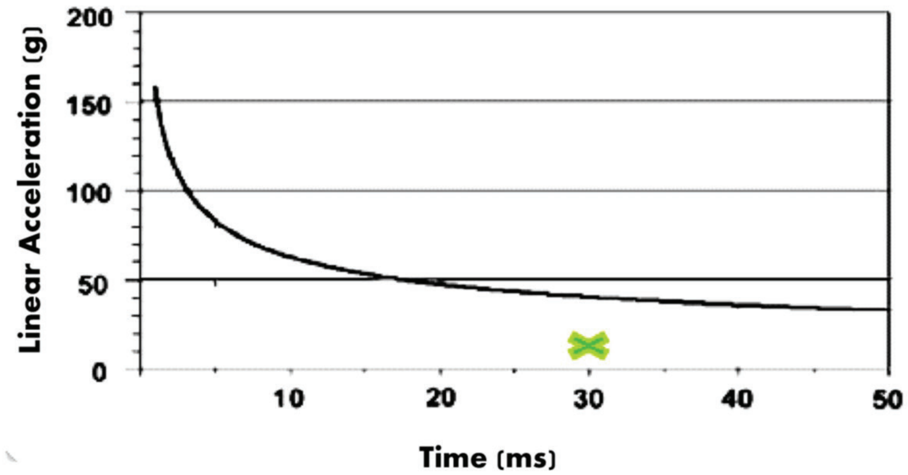

FIGURE 3. Comparison of Obtained Linear Acceleration with The Threshold Tolerance Curve of the head injury

irreversible brain injury. While the combinations below the curve do not exceed human tolerance, they may result in reversible injuries (Ommaya et al., 2002). In the current study, the average and peak of linear acceleration caused by a punch were obtained 20 g and 75 g, respectively. Also, their durations were 30 ms and 3 ms, respectively (Figure 2). According to the WSTC, these amounts are located below the curve; therefore, they cannot lead to severe damage.

Atha et al. conducted some experiments for a heavyweight boxer using a ballistic pendulum (Atha, Yeadon, Sandover, & Parsons, 1985). They obtained a peak of linear acceleration as 53 g. Smith et al. also gained a linear acceleration of 43.6 g for punches from boxers (Smith, Dyson, Hale, & Janaway, 2000). Fife et al. reported that the peak of linear acceleration resulting from a punch to the head is 71.23 g (Fife, O'Sullivan, & Pieter, 2013). Walilko et al. assumed the peak of linear acceleration for Olympic boxers' punch, 58g (Walilko et al., 2005). All these researchers used the threshold of head injury for linear acceleration proposed by Ommaya et al. (2002). The risk of traumatic brain injury from these straight punches inducing translational acceleration is low (less than 2%). Therefore, it can be stated that the results obtained from the present study are in accordance with these previous studies.

It should be noted that if the head is exposed to such accelerations repeatedly, the tolerance and resistance may decrease against the impacts due to the presence of frequent tensions, which leads to the increased duration of acceleration or rising of acceleration amount, which will likely be accompanied by the displacement of the intersection location of the acceleration and time to above the WSTC. In other words, irreversible injuries occur. Since boxers are exposed to repeated blows to the head, this can lead to brain injury in the long term.

The current study also showed the average and peak of rotational accelerations of the head as 1140 rad/s^2 and 4036 rad/s^2, respectively. According to Löwenhielm's study, head acceleration of 4500 rad/s^2 causes the rupture of the bridging veins in the brain (Löwenhielm, 1975). An angular acceleration of 1800 rad/s^2 was also proposed as the tolerance level for a 50% probability of concussion by Ommaya et al. (2002). Therefore, in our study, the obtained rotational acceleration put boxer athletes at risk for concussion.

However, the 4036 rad/s^2 rotational acceleration is less than the injury threshold of Löwenhielm (1975); nevertheless, it may be accompanied by serious damage of the veins in the brain in repetitive blows to the head. In some other studies, different results were reported, which can be for various methods of testing or some properties and conditions of punches to the head such as the studies of Rowson et al. (2012) and Walilko et al. (2005). Rowson et al. determined that rotational acceleration created within the head is 1753 rad/s^2 via a simulation of punching in boxing. Walilko et al. reported that rotational acceleration caused by the punch of a 109 kg person to head, is 6343 rad/s^2 (Rowson et al., 2012; Walilko et al., 2005).

Generally, according to the results obtained in the current study, it can be stated that in the boxing head injuries, rotational acceleration is suspected of playing a significant role. Therefore, it should receive considerable attention. Probably, the translational component of acceleration in punching can be more easily resisted by neck muscles; therefore, greater muscle strength may increase its resistance against impact force and linear acceleration (Schmitt et al., 2019). The structure and physical properties of brain tissue also are more resilient to compressive and tensile forces than rotational and shearing forces. As such, the translational acceleration injury threshold is higher than the rotational acceleration thresholds. So, the threshold of head injury tolerance for rotational acceleration is much lower due to the resistance of brain tissue layers against the shearing force that leads to rotation and the creation of shearing in brain tissue. Hence, rotational acceleration is associated with higher injury risk (Campbell, Gallagher, McLeod, O'Neill, & McMillan, 2019; Schmitt et al., 2019).

The model simulated in this study is based on previous studies and is related to the general state of the biomechanical behaviour of the athlete's head. However, it should be considered that, in reality, everyone has different biomechanical behaviour and responses, which is not possible to simulate. Also, it should be noted that there is no possibility of biomechanically isolating the linear acceleration from the rotational acceleration in sport activities. Therefore, the consideration of both linear and rotational acceleration parameters for head injury thresholds is advised in order to examine more appropriate dynamic response of the head for future studies.

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Furthermore, to decrease the risk of brain injuries in boxing athletes, we recommend proper defensive techniques be practised and employed. To reduce the risk of concussion from punching, it is also suggested that, several measures be applied by the World Boxing Federation, including rules changes and proper headgears design.

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References

Atha, J., Yeadon, M., Sandover, J., & Parsons, K. (1985). The damaging punch. *Br Med J (Clin Res Ed), 291*(6511), 1756-1757. doi: 10.1136/bmj.291.6511.1756

Beaudouin, F., Aus der Fünten, K., Tröß, T., Reinsberger, C., & Meyer, T. (2019). Head injuries in professional male football (soccer) over 13 years: 29% lower incidence rates after a rule change (red card). *British journal of sports medicine, 53*(15), 948-952. doi: 10.1136/bjsports-2016-097217

Beaudouin, F., Aus der Fünten, K., Tröß, T., Reinsberger, C., & Meyer, T. (2020). Match Situations Leading to Head Injuries in Professional Male Football (Soccer)—A Video-Based Analysis Over 12 Years. *Clinical Journal of Sport Medicine, 30*, S47-S52. doi: 10.1097/jsm.0000000000000572

Boroushak, N., Eslami, M., Kazemi, M., Daneshmandy, H., & Johnson, J. A. (2018). The dynamic response of the taekwondo roundhouse kick to head using computer simulation. *Ido Movement for Culture. Journal of Martial Arts Anthropology, 18*(2), 54-60. doi: 10.14589/ido.18.2.8.

Campbell, I. N., Gallagher, M., McLeod, H. J., O'Neill, B., & McMillan, T. M. (2019). Brief compassion focused imagery for treatment of severe head injury. *Neuropsychological rehabilitation, 29*(6), 917-927. doi: 10.1080/09602011.2017.1342663

Chen, Y. (2012). *Biomechanical analysis of traumatic brain injury by MRI-based finite element modeling.* University of Illinois at Urbana-Champaign.

Denny-Brown, D., & Russell, W. R. (1941). Experimental cerebral concussion. *Brain, 64*(2-3), 93-164. doi: 10.1093/brain/64.2-3.93

Fife, G., O'Sullivan, D., & Pieter, W. (2013). Biomechanics of head injury in Olympic taekwondo and boxing. *Biology of sport, 30*(4), 263-238. doi: 10.5604/20831862.1077551

Hoshizaki, T. B., Post, A., Oeur, R. A., & Brien, S. E. (2014). Current and future concepts in helmet and sports injury prevention. *Neurosurgery, 75*(suppl_4), S136-S148. doi: 10.1227/NEU.0000000000000496

Kis, M., Saunders, F. W., Kis Sr, M., Irrcher, I., Tator, C. H., Bishop, P. J., & Martin, W. (2013). A method of evaluating helmet rotational acceleration protection using the Kingston Impact Simulator (KIS Unit). *Clinical Journal of Sport Medicine, 23*(6), 470-477. doi: 10.1097/JSM.0b013e318295a80f

Löwenhielm, P. (1975). Mathematical simulation of gliding contusions. *Journal of Biomechanics, 8*(6), 351-356. doi: 10.1016/0021-9290(75)90069-X

Motherway, J., Doorly, M. C., Curtis, M., & Gilchrist, M. D. (2009). Head impact biomechanics simulations: A forensic tool for reconstructing head injury? *Legal Medicine, 11*, S220-S222. doi: doi.org/10.1016/j.legalmed.2009.01.072

Oeur, A. (2012). *An analysis of head impact angle on the dynamic response of a Hybrid III headform and brain tissue deformation*: University of Ottawa (Canada).

Ommaya, A., Goldsmith, W., & Thibault, L. (2002). Biomechanics and neuropathology of adult and paediatric head injury. *British journal of neurosurgery, 16*(3), 220-242. doi: 10.1080/02688690220148824

Putukian, M., Echemendia, R. J., Chiampas, G., Dvorak, J., Mandelbaum, B., Lemak, L. J., & Kirkendall, D. (2019). Head Injury in Soccer: From Science to the Field; summary of the head injury summit held in April 2017 in New York City, New York. *British journal of sports medicine, 53*(21), 1332-1332. doi: 10.1136/bjsports-2018-100232.

Rowson, S., Brolinson, G., Goforth, M., Dietter, D., & Duma, S. (2009). Linear and angular head acceleration measurements in collegiate football. *Journal of biomechanical engineering, 131*(6). doi: 10.1115/1.3130454

Rowson, S., Duma, S. M., Beckwith, J. G., Chu, J. J., Greenwald, R. M., Crisco, J. J., Maerlender, A. C. (2012). Rotational head kinematics in football impacts: an injury risk function for concussion. *Annals of biomedical engineering, 40*(1), 1-13. doi: 10.1007/s10439-011-0392-4

Schmitt, K.-U., Niederer, P. F., Cronin, D. S., Morrison III, B., Muser, M. H., & Walz, F. (2019). Head injuries *Trauma Biomechanics* (pp. 87-115): Springer.

Schmitt, K.-U., Niederer, P. F., Cronin, D. S., Muser, M. H., & Walz, F. (2014). Verletzungen der Wirbelsäule *Trauma-Biomechanik* (pp. 91-131): Springer.

Smith, M., Dyson, R., Hale, T., & Janaway, L. (2000). Development of a boxing dynamometer and its punch force discrimination efficacy. *Journal of sports sciences, 18*(6), 445-450. doi: 10.1080/02640410050074377

Viano, D. C., Casson, I. R., Pellman, E. J., Bir, C. A., Zhang, L., Sherman, D. C., & Boitano, M. A. (2005). Concussion in professional football: comparison with boxing head impacts—part 10. *Neurosurgery, 57*(6), 1154-1172. doi: 10.1227/01.NEU.0000187541.87937.D9

Walilko, T., Viano, D. C., & Bir, C. A. (2005). Biomechanics of the head for Olympic boxer punches to the face. *British journal of sports medicine, 39*(10), 710-719. doi: 10.1136/bjsm.2004.014126

Winter, D. A. (2009). *Biomechanics and motor control of human movement*: John Wiley & Sons. doi: 10.1002/9780470549148

Wu, L., Chung, J. Y., Saith, S., Tozzi, L., Buckley, E. M., Sanders, B., . . . Lok, J. (2019). Repetitive head injury in adolescent mice: A role for vascular inflammation. *Journal of Cerebral Blood Flow & Metabolism, 39*(11), 2196-2209. doi: 10.1177/0271678X18786633

Zong, Z., Lee, H., & Lu, C. (2006). A three-dimensional human head finite element model and power flow in a human head subject to impact loading. *Journal of Biomechanics, 39*(2), 284-292. doi: 10.1016/j.jbiomech.2004.11.015

ORIGINAL SCIENTIFIC PAPER

Accuracy in Archery Shooting is linked to the Amplitude of the ERP N1 to the Snap of Clicker

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Abstract

An archer requires a well-balanced and highly reproducible release of the bowstring to attain high scores in competition. Recurve archers use a mechanical device called the "clicker" to check the draw length. The fall of the clicker that generates an auditory stimulus should evoke a response in the brain. The purpose of this study is to evaluate the event-related potentials during archery shooting as a response to the fall of the clicker. Fifteen high-level archers participated. An electro cap was placed on the archers' scalps, and continuous EEG activity was recorded (digitized at 1000 Hz) and stored for off-line analysis. The EEG data were epoched beginning 200 ms before and lasting 800 ms after stimulus marker signals. An operational definition has been developed for classifying hits corresponding to hit and/or miss areas. The hit area enlarged gradually starting from the centre of the target (yellow: 10) to blue (6 score) by creating ten hit area indexes. It is found that the snap of the clicker during archery shooting evokes N1–P2 components of long-latency evoked brain potentials. N1 amplitudes are significantly higher in hit area than that of miss areas for the 2nd and 4th indexes with 95% confidence intervals and 90% confidence intervals for the 1st and 3rd indexes with 90% confidence intervals. We conclude that the fall of the clicker in archery shooting elicits an N1 response with higher amplitude. Although evoked potential amplitudes were higher in successful shots, their latencies were not significantly different from the unsuccessful ones.

Keywords: *archery, evoked brain potentials, auditory evoked brain potentials, n1-p2 component, archery performance*

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Introduction

Understanding the basic neural processes that underlie complex higher-order cognitive operations and functional domains is a fundamental goal of cognitive neuroscience (Light et al., 2010). Electroencephalography (EEG) is the neurophysiological method of recording the electrical activity generated by the brain via electrodes placed on the surface of the scalp (Woodman, 2010). Many EEG researchers utilize an event-related potential (ERP) experimental design in which a large number of time-locked experimental trials are averaged together, allowing the investigator to probe sensory, perceptual, and cognitive processing with millisecond precision (Light et al., 2010). ERPs are EEG changes that are time-locked to sensory, motor, or cognitive events that provide a

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safe and non-invasive approach to studying the psychophysiological correlates of mental processes. They can be elicited by a wide variety of sensory, cognitive, or motor events (Sur & Sinha, 2009).

Cheron and colleagues (2016) observed that the brain dynamics that determine both motor control and crucial psychological factors, such as intrinsic motivation, selective attention, goal setting, working memory, decision-making, positive self-concept, and self-control, need to be taken into account for top performance in sports. Being aware of this, sports professionals (e.g., sport scientists, coaches, mentors, etc.) have become interested in brain imaging, both as a route to a better understanding of the basic mechanisms underlying sporting behaviour, and as a means to develop new methods to enhance performance (Park et al., 2015).

Archery is a static sport with a stable sequence of movements throughout the shot. Archers perform a proper stance position and draw the bowstring with a three-finger hook. As they reach the final drawing position, they need to synchronize aiming, drawing and the draw length. A device called "clicker" has been developed to make a draw length check. When the clicker snaps against the bow handle, it creates a "click" sound. After sensing the clicker's signal, the archer relaxes the flexor group muscles of the forearm and actively contracts the extensors to produce the release (Ertan et al., 2003).

Some studies have analysed brain electrical activity during archery shooting (Salazar et al., 1990; Landers et al., 1991; Landers et al., 1994). However, there is no study evaluating the response to the fall of the clicker in the human brain in the literature. The electrical activity of the archers' brain was also not measured in the field setting until now. The snap of the clicker, which is an exogenous acoustic stimulus, is expected to evoke N1-P2 components of the long latency ERPs that should also be obtained in the field. The present study, therefore, aimed to investigate the ERPs in Recurve Archery, more specifically the N1-P2 components, and to determine if they have any relation with successful and unsuccessful shots.

It is hypothesized that the amplitude of the N1-P2 components will be higher in successful shots going to the centre of the target.

Methods

An experimental research study has been designed to evaluate the responses of archer's brain to the event in recurve archery shooting. The brain responds to the fall of the clicker paired with the hit on the target. The hits and the corresponding brain responses were grouped as successful and unsuccessful shots and their corresponding brain responses.

Participants

All participants were informed about the possible risks associated with the experiment before the commencement of the trial. This study was approved in advance by the Medical Ethical Committee of Baskent University, Medical Faculty Ankara (Certificate No: 2004/85). Informed consent was obtained from all individual participants. The study conformed to the ethical requirements of the 1975 Helsinki Declaration. The participants of the present study were 15 archers (9 males; 6 females) for archery shooting experiments. The mean age of the archers was 22.8 years (range 16–31 yrs.). The mean years of archery experience and the highest FITA scores were 5.8 years (range 2–14 yrs.) and 632 (70 m score: range 602–661), respectively.

Archers performed twelve trial shots to become acquainted with the measurement conditions before the main experiment. All participants reported normal hearing, had medical histories free of significant neurological problems and were not taking medication known to affect brain activity.

Procedure

Shootings were performed from 18 m, which is the official competition distance to the target' face (WA, 2019). Continuous EEG activity of each subject recorded at a 1000 Hz sampling rate during the test and stored for off-line analysis (Picture 1).

PICTURE 1. The placement of the electro cap on the scalp of an archer in the field setting

As the arrow was pulled beyond the clicker, the clicker-lever fell on the bow-handle, which conveyed the signal to the archer that the arrow was appropriately positioned and is ready to be released (Ertan et al., 2003; Ertan et al., 2005a). A mechanical switch was attached under the clicker to superimpose the fall of the clicker with the EEG recordings. The

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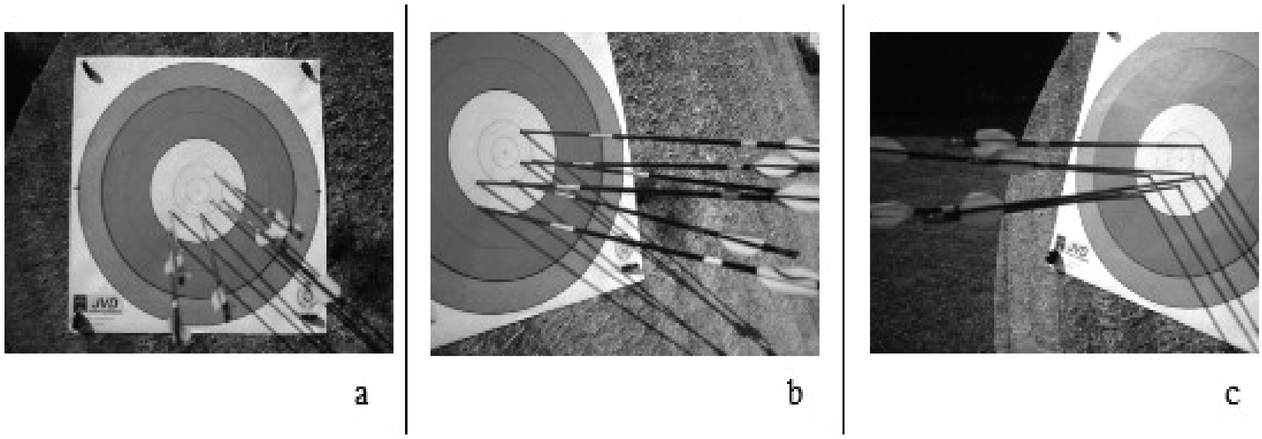
Table 1. Number of arrows shot by each participant and the calculation of hit and miss areas

Area Index	kx= ky=	Hit/ Miss Area	Participant															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
			Number of Shots for Each Participant															
			70	72	72	72	72	72	72	72	72	72	72	64	72	72	72	1070
1	0.3 0.3	Hit	2	4	4	6	2	4	8	2	5	5	2	6	5	5	5	65
		Miss	68	68	68	66	70	68	64	70	67	67	70	58	67	67	67	1005
2	0.4 0.4	Hit	4	5	5	12	4	9	10	4	11	5	7	9	6	11	6	108
		Miss	66	67	67	60	68	63	62	68	61	67	65	55	68	61	68	962
3	0.5 0.5	Hit	7	9	6	16	8	14	14	6	19	8	17	10	10	15	11	169
		Miss	63	63	68	56	64	58	58	68	53	64	55	54	62	57	61	901
4	0.6 0.6	Hit	12	13	10	19	13	18	19	9	20	17	19	16	13	18	16	232
		Miss	58	59	62	53	59	54	53	63	52	55	53	48	59	54	56	838
5	0.7 0.7	Hit	17	19	14	24	19	21	25	14	24	27	21	18	18	28	24	313
		Miss	53	53	58	48	53	51	47	58	48	45	51	46	54	44	48	757
6	0.8 0.8	Hit	23	20	19	32	20	23	30	19	27	28	22	20	25	35	26	369
		Miss	47	52	53	40	52	49	42	53	45	44	50	44	47	37	46	701
7	0.9 0.9	Hit	28	26	25	35	22	27	33	30	32	32	25	26	33	38	32	444
		Miss	42	46	47	37	52	45	39	42	40	40	47	38	39	34	40	626
8	1.0 1.0	Hit	34	34	30	37	27	34	37	34	37	36	31	34	35	42	36	518
		Miss	36	38	42	35	45	38	35	38	35	36	41	38	37	30	36	552
9	1.1 1.1	Hit	38	40	38	39	34	40	39	39	44	42	34	36	40	48	39	590
		Miss	32	32	34	33	38	32	33	33	28	30	38	28	32	24	33	480
10	1.2 1.2	Hit	41	44	42	41	42	45	44	43	45	48	40	41	44	51	41	652
		Miss	29	28	30	31	30	27	28	29	27	24	32	23	28	21	31	418

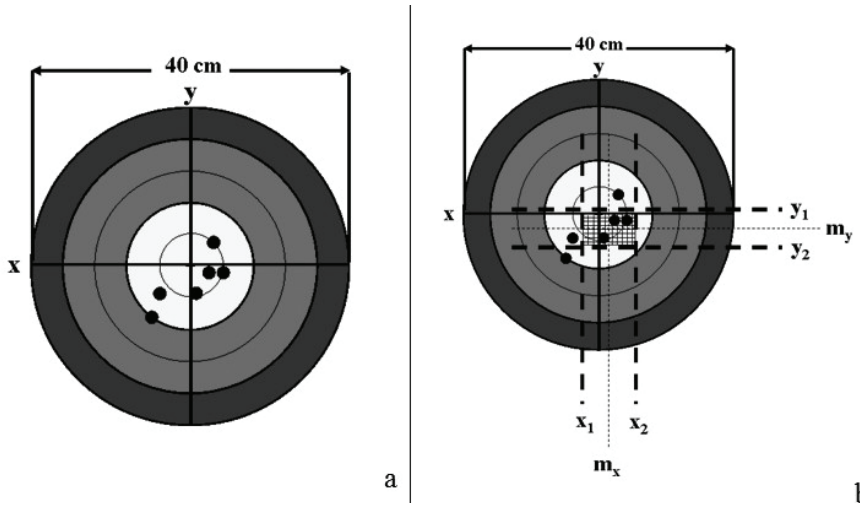
Note: 15 participants shot a total of 1070 arrows. The first archer, for example, shot 70 arrows. Area index starting from the most central (Area Index 1) to the outer surface of the target face (Area Index 10). The first archer shot 2 arrows to the centre (hit area) and 68 arrows outside the hit area of the target in Index 1. The hit area increased gradually and the ERPs corresponding to hit and miss area compared. Please refer to Pictures 2 and 3 for calculation of hit and miss areas and Figure 2 for demonstration of the hit and miss areas and gradual increase of hit area. Figure 2 also illustrates the grand mean averages of ERPs corresponding to the hit and miss area.

archers shot 1070 arrows in total (Table 1). The order of shots was controlled by assigning colours and numbers on each arrow, which was necessary to comprehend the exact order of each arrow to pair the shots with EEG traces.

Photos were taken on the target face after each found of shooting. The front view of the picture was used to decide the place of the arrow on the target (Picture 2a). Moreover, two more photos were taken for each end from both sides to use to determine hits on the target face accurately (Picture 2 b and c). Hits of an archer in each end were processed by placing them on a coordinate system for further analysis (Picture 3). All these hits were paired with their temporally matched single sweeps of EEG recordings. Finally, hits were grouped as falling into the hit-area and miss-area with their corresponding EEG recordings.



PICTURE 2. The processing of the hits on the target (a) front view of the hits that is used for analysis, (b) left view and (c) right views were used for determining the order of shot.



PICTURE 3. Processing the hits on the target by placing them on the coordinate system and grouping them as being in hit-area and miss-area.

The hit-area is defined as the rectangle between (x_1, y_1), (x_1, y_2), (x_2, y_1), (x_2, y_2) and the miss-area is the outer part of the hit-area on the target face (Picture 3b). Hits on the target were divided into two areas: hit-area and miss-area according to the formula given below:

$x_1=m_x - k_x$
$x_2=m_x + k_x$
$y_1=m_y - k_y$
$y_2=m_y + k_y$, where
m_x: mean of x-values of hits
m_y: mean of y-values of hits
k: a positive real number

The hit area was increased and/or decreased by changing the k_x and k_y values. The number of arrows was summarized corresponding to hit and miss areas for different values of k_x and k_y; they are shown in Table 1. Comparisons of successful and unsuccessful shots were made by assigning real numbers to k_x and k_y, respectively. For example, when "0.3" assigned to both k_x and k_y, the total number of arrows in the hit and miss area were calculated as 65 and 1005 respectively out of the total number of 1070 shots. The EEG traces coinciding with hit area were compared with that of the traces of the miss area.

EEG Recordings

The EEG was recorded with Ag/AgCl electrodes mounted in an elastic cap (Electro-Cap). A recording gel (Electro-Gel, a product of Electro-Cap International, Inc.) was injected into the electrodes. Impedances were below 5KΩ in all electrode sites. The EEG derivations (scalp sites) that were used were based on the "International 10-20" system (Jasper, 1958) and recent guidelines of the Society for Psychophysiological Research (Pivik et al., 1993) for EEG/ERP research (Fp1, Fp2, F3, F4, F7, F8, Fz, C3, C4, P3, P4, Pz, T3, T4, T5, T6, O1, O2, Right Mastoid, Left Mastoid).

Data Processing

The EEG data were epoched beginning 200 ms before and lasting 800 ms after the fall of the clicker. Each epoch was bandpass filtered (1–12 Hz, Butterworth 12 dB/oct slopes). The maximum amplitudes and peak latencies of the auditory N1 and the P2 ERP components were measured manually using the signal-processing tool in Matlab. Considering the supratemporal cortical origin and tangential dipolar orientation of the N1-P2 component of ERPs (Naatanen and Picton, 1987), the M_2 electrode was chosen to be the site of measurement for both N1 and P2 referenced to Cz (Golob et al., 2002).

Statistical Analysis

The means of the N1 amplitudes, N1 latencies, P2 amplitudes, and P2 latencies for each index and the hit-miss mean values for each area were calculated. Confidence Intervals (CIs) used to evaluate the ERPs corresponding to hit and/or miss areas N1 and P2 amplitudes and latencies respectively; 95% and 90% confidence levels were selected for each index and ERP component. The lower and upper limits of the mean ERPs difference between the hit and miss areas are given. When the CI does not include the value of zero effect, it is assumed that there is a statistically significant result in between ERPs corresponding to hit and miss areas (Du Prel, et al., 2009).

Results

Figure 1 shows the differences for the N1 amplitude (A), N1 latency (B), P2 amplitude (C) and P2 latency (D) for ERP differences between hit and miss areas. If CI does not include the value of zero effect, it was assumed that there is a statistically significant difference for any of confidence levels. When the value 0 is within 95% CI or 90% CI separately, the differences of the mean ERPs between the hit and miss areas are found to be not significant. The significant differences were observed when the value 0 is outside 95% or 90% CIs in between ERPs corresponding to defined target areas.

Figure 1A illustrates the comparison of N1 amplitudes for hit and miss areas. N1 amplitudes are significantly higher in hit area than that of miss areas for the 2nd and 4th indexes with 95% CI and the 1st and 3rd with 90% CI. There is no significant difference between the means of N1 latencies (Figure 1B), P2 amplitudes (Figure 1C) and P2 latencies (Figure 1D) for any of the area indices, as value 0 (zero) is within the CIs in all of them.

Figure 1 also compares ERP components recorded during archery shooting for the hit and miss areas defined earlier. It includes the N1 amplitudes, N1 latencies, P2 amplitudes,

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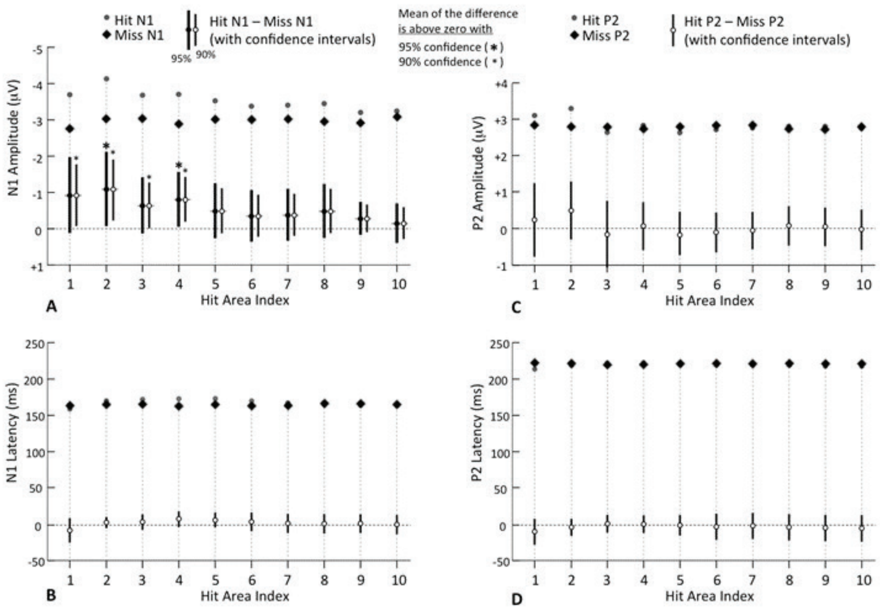

FIGURE 1. Confidence intervals of the N1 amplitudes, N1 latencies, P2 amplitudes and P2 latencies for the ERPs associated with hits and misses. The N1 amplitudes, N1 latencies, P2 amplitudes and P2 latencies for the ERPs associated with hits and misses are given as the difference between these means for each of the area indexes shown by empty circles with confidence intervals around them. Hit area indices increase as the hit area is enlarged from centre to outer surface of the target. The differences of the means are shown with the 95% and 90% confidence intervals for each index and ERP component.

and P2 latencies of the ERPs. As the hit area is enlarged, the number of arrows and their paired EEG traces increases corresponding to the hit area. The reader should refer to Table 1 for the exact number of arrows and their paired EEG traces for each participant and the whole group the hit and miss areas defined earlier. Figure 2 shows grand averaged ERPs, which were aligned to the N1 wave in order to emphasize the N1 amplitude difference between the hit and miss shots.

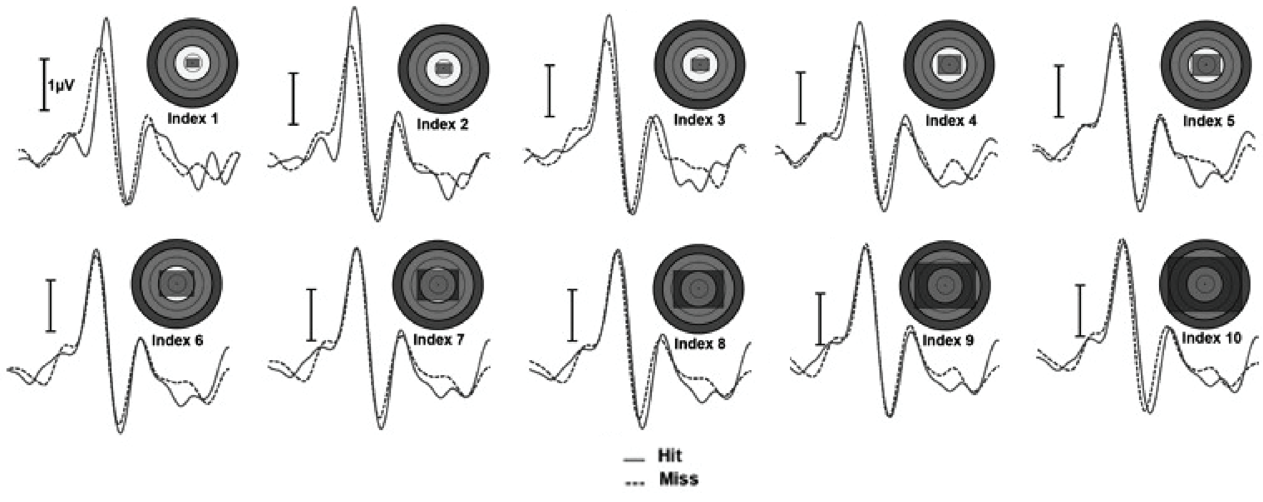

FIGURE 2. Grand averages of ERPs, which were aligned to N1.

Our results show that we can reject the null hypothesis for the N1 amplitudes corresponding to the 2nd and 4th indexes with 95% CI and the 1st and 3rd with 90% CI. We failed to reject the null hypothesis for all of the N1 amplitudes except for the 1st to 4th indexes, N1 latency, P2 amplitude, and P2 latency.

Discussion

There are some studies analysing brain electrical activity during archery shooting (Salazar et al., 1990; Landers et al., 1991; Landers et al., 1994). However, there is no study in the literature evaluating the response in the human brain to the fall of the clicker. Therefore, the purpose of the current study was to investigate the archers' brain responses to the fall of the clicker, as it is a sound that creates long latency ERPs. Pilot studies of our research group have shown that response to the event (fall of the clicker) evokes the N1-P2 component. However, it is not very well established whether there is any difference between the responses to the event during successful (hit area) and unsuccessful (miss area) shots in terms of amplitude and latency profiles. Ten different success areas have been defined by enlarging the defined area starting from the centre of the target face to the outer parts of it. The hits in the hit area and their corresponding EEG traces were compared if there is any difference between these two area responses. The 15 archers made a total of 1070 shots during the measurements. All these shots were matched with the single sweeps of EEG recordings. Finally, hits were grouped as falling into the hit-area and miss-area with their corresponding EEG recordings. Thus, ERPs were achieved corresponding for hit and miss areas separately.

The findings have proved that when the archers shoot to the centre of the target, their N1 amplitudes are higher than that of the N1 amplitudes corresponding to the hits in the outer surface of the hit area. Therefore, a question arises regarding what the reason may be for the N1 amplitude increase. Why is the N1 amplitude higher when archers shoot in the centre of the target? We will attempt to discuss the reason(s) by referring to the studies related to N1-P2 specifications.

When an archer reaches full draw position, he/she continues aiming at the target while simultaneously drawing the bowstring. The bowstring is released when an impetus is received from a device called "clicker". Each arrow can be drawn to an exact distance, and a release can be obtained and maintained by this device. The clicker is reputed to improve the archer's score and is used by all target archers (Leroyer et al., 1993; Ertan et al., 2011). The archer should react to the clicker as quickly as possible, and synchronize the muscle activity of the whole body to attain eventual optimal accuracy. In particular, there should be a repeated contraction and relaxation of archery-specific muscle groups during archery training and competitions according to the high number of arrows (Ertan et al., 2003).

The fall of the clicker creates a "click" sound when it falls from the tip of the arrow and hits the bow handle. Its mechanical fall also generates some vibrations on the bow handle that may be sensed by archer through the bow arm palm and fingers. Therefore, as the fall of the clicker is considered to be a stimulus evoking some brain potentials, this response may not be a simple one, which is evoked by an isolated stimulus. The brain response to the fall of the clicker was thought to be a combination of auditory, tactile and/or visual stimulus response. It should also be kept in mind that during the full draw and aiming, the archer is in full concentration and his/her attention is directed to some selected cues, such as the target and the clicker's fall (Ertan et, al., 2005b).

We found that the fall of the clicker evokes N1-P2 components of ERPs in archery. Several different cerebral processes contribute to the N1 wave of the scalp-recorded ERPs (Näätänen & Picton, 1987). The N1 wave of the ERPs was larger when the participant was reacting with the stimuli than ignoring them (Woodman, 2010). An increased attentiveness level of a subject is reported, causing a higher amplitude of N1 and a lower amplitude of P2 (Crowley & Colrain, 2004). When considered to be the behavioural and cognitive processes of selectively concentrating on a discrete aspect of information, while ignoring other perceivable information, attention is accompanied by a general and nonspecific increase in cerebral excitability, which might increase the amplitude of the N1 wave (Light et al., 2010).

Temporal and event uncertainty is also known to increase the N1 amplitude (Klemmer, 1956). In addition, the responses to probe stimuli presented during tasks other than fore-period reaction time paradigms have also suggested that arousal enhances the N1 amplitude (Eason & Dudley, 1971; Picton et al., 1979). The N1 evoked by unattended auditory stimuli is also found to be larger at higher levels of alertness, as estimated on the basis of the pre-stimulus EEG (Woodman, 2010). Moreover, Wilkinson et al. (1966) demonstrated that increasing motivation by making the amount of monetary reward dependent on performance has resulted in enhanced N1 amplitudes and better performance (Wilkinson & Morlock, 1966; Furley et al., 2017).

The archer pushes the bow handle with the extended arm and pulls the string with a three-finger hook on the drawing arm. When he/she reaches the final position, the archer should accomplish and/or synchronize some tasks at the same time. As long as the archer pulls the point of arrow beyond the clicker, the onset of the click sound cannot be considered like pressing a button and/or delivering the stimuli by a machine. The archer receives foreknowledge of the timing of the stimulus from the vibrations on the tip of the arrow. However, the timing of the onset of the trigger is not totally under the control of the archer. The mentioned temporal and/or time uncertainty of the timing of the stimulus may have caused an increase in the N1-P2 amplitude. The rather high amplitude of the N1-P2 response, which would not have been expected to be elicited by a relatively weak sound like the one created by the clicker, may be explained by the findings of earlier studies reporting larger N1 amplitudes when there is uncertainty in stimulus timing (Volosin et al., 2016). The observation that the N1 latency is longer for stimuli with timing uncertainty, which is reported in the same study, may also explain the relatively longer latency of the N1 in the present study.

As for the effect of prior preparation for performing a demanding task, one should understand the details of archery shooting to explain the effect of the type of task on ERPs. An archer pushes the bow with an extended arm, which is statically held in the direction of the target, while the other arm exerts a dynamic pulling of the bowstring from the beginning of the drawing phase until the release is dynamically executed (Leroyer et al., 1993; Simsek et al., 2018). The release phase must be well balanced and highly reproducible to achieve commendable results in a competition (Ertan et al., 2011). The archer should react to the clicker as quickly as possible. In particular, a repeated contraction and relaxation strategy in the forearm and pull finger muscles should be developed for this reason (Ertan et al., 2003, 2005a, Soylu et al., 2006). That is why archery shooting can be considered to be a highly demanding task, which may also be one of the reasons that the N1 amplitude is higher when the archer achieves to hit the centre of the target.

Another possible explanation is the archer's high visual attention while shooting. It could be considered that when the archers reached high visual attention, the clicker's sound may plausibly be an irrelevant stimulus. Kramer and colleagues (1995) reported that mental workload leads to higher N1 amplitude; moreover, they argued that N1 amplitude could be used as an indicator of mental workload. Considering that the high mental workload consumes limited resources of attention (Mun et al., 2017), it is likely that possible high mental workload could be responsible for low N1 amplitude during missed shots.

There is some evidence for a task- or attention-induced stimulus-nonspecific increase in the excitability of some neuronal populations contributing to the N1 deflection. This increase causes the N1 amplitude to any input, relevant or irrelevant, to be larger when the subject is engaged in a specific task rather than relaxing, and larger when performing a more

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involved task rather than a less involved one. However, none of these findings exemplifies the performance as archery does because "performance" means the speed of the response (Reaction Time paradigm) in earlier studies, not the outcome of the performance. Ertan and colleagues (1996) researched archers to measure the effect of reaction time on the scores on the target. They have concluded that there was no correlation between the hits on the target and the reaction times of the participant.

We concluded that the fall of the clicker in archery shooting elicits an N1 response with larger amplitude for successful shots than unsuccessful ones, which can be explained by the highly motivated and attentive state of the archer, by the timing uncertainty of the clicker's fall, by the mental workload, and by the fact that the response is not solely to the clicker's sound but also to the tactile and visual stimuli created when it falls. A significant increase in response was observed when the archer hits the centre of the target. We were, however, unable to determine a significant difference between successful and unsuccessful shots in terms of N1 latency and/or P2 amplitude and latency as a response to the fall of the clicker. It is recommended that archers and their coaches receive regular support using biofeedback methods to evaluate their psychological states just before and/or after the fall of the clicker.

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References

Cheron, G., Petit, G., Cheron, J., Leroy, A., Cebolla, A., Cevallos, C., ... & Dan, B. (2016). Brain oscillations in sport: toward EEG biomarkers of performance. *Frontiers in Psychology*, *7*, 246. doi: 10.3389/fpsyg.2016.00246

Crowley, K. E., and Colrain, I. M. (2004). A review of the evidence for P2 being an independent component process: Age, sleep and modality. *Clinical Neurophysiology,* 115, 732–744. doi: 10.1016/j.clinph.2003.11.021

Du Prel, J. B., Hommel, G., Röhrig, B., & Blettner, M. (2009). Confidence interval or p-value?: part 4 of a series on evaluation of scientific publications. *Deutsches Ärzteblatt International*, *106*(19), 335. doi: 10.3238/arztebl.2009.0335

Eason, R. G., & Dudley, L. M. (1971). Effect of stimulus size and retinal locus of stimulation on visually evoked cortical responses and reaction in man. *Psychonomic Science*, *23*(5), 345-347. doi: 10.3758/BF03336143

Ertan H., Kentel B., Tümer S. T., Korkusuz F. (2003). Activation Patterns in Forearm Muscles during Archery Shooting. *Human Movement Science*, 22, 37-45. doi: 10.1016/S0167-9457(02)00176-8

Ertan, H., & Acikada, C. (1996). The Effect of Clicker Reaction Time on Scoring Points and The Relationship between Visual, Auditory and Tactile Reaction Times on Turkish National Archery Team. *Hacettepe Journal of Sport Sciences*, *7*(3), 12-20

Ertan, H., Kentel, B. B., Tümer, S. T., & Korkusuz, F. (2005b). Reliability and validity testing of an archery chronometer. *Journal of sports science & medicine,* 4(2), 95.

Ertan, H., Knicker, A. J., Soylu, R.A. & Strueder, H.K. (2011). Individual variation of bowstring release in Olympic archery: A comparative case study. *Human Movement*, 12(3): 273- 276. doi: 10.2478/v10038-011-0030-x

Ertan, H., Soylu, A. R., Korkusuz, F. (2005a). Quantification the Relationship Between FITA Scores and EMG Skill Indexes in Archery. *Journal of Electromyography and Kinesiology*, 15(2), 222-7. doi: 10.1016/j.jelekin.2004.08.004

Furley, P., Schnuerch, R., & Gibbons, H. (2017). The winner takes it all: Event-related brain potentials reveal enhanced motivated attention toward athletes' nonverbal signals of leading. *Social neuroscience*, *12*(4), 448-457. doi: 10.1080/17470919.2016.1182586

Golob E. J., Pratt H., Starr A. (2002) Preparatory slow potentials and event-related potentials in an auditory cued attention task. *Clinical Neurophysiology*, 113, 1544–1557. doi: 10.1016/S1388-2457(02)00220-1

Jasper, H. H. (1958). *The ten-twenty electrode system of the international federation. Electroencephalography and Clinical Neurophysiology*, 10, 371-558. (cited by) Pivik, R. T., Broughton, R. J., Coppola, R., Davidson, R. J., Fox, N., & Nuwer, M. R. (1993). Guidelines for the recording and quantitative analysis of electroencephalographic activity in research contexts. *Psychophysiology*, 30, 547-558.

Klemmer, E. T. (1956). Time uncertainty in simple reaction time. *Journal of Experimental Psychology*, *51*(3), 179. doi: 10.1037/h0042317

Kramer, A.F., Trejo, L.J., and Humphrey, D. (1995). Assessment of mental workload with task-irrelevant auditory probes. *Biological Psychology,* 40, 83–100. doi: 10.1016/0301-0511(95)05108-2

Landers, D. M., Han, M., Salazar, W., & Petruzzello, S. J. (1994). Effects of learning on electroencephalographic and electrocardiographic patterns in novice archers. *International Journal of Sport Psychology*, *25*(3), 313–330

Landers, D. M., Petruzzello, S. J., Salazar, W., Crews, D. J., Kubitz, K. A., Gannon, T. L., & Han, M. (1991). The influence of electrocortical biofeedback on performance in pre-elite archers. *Medicine & Science in Sports & Exercise*, *23*(1), 123–129. doi: 10.1249/00005768-199101000-00018

Leroyer, P., Hoecke, J. V., Helal, J. N. (1993). Biomechanical study of the final push-pull in archery. *Journal of Sports Sciences*, 11, 63-69. doi: 10.1080/02640419308729965

Light, G. A., Williams, L. E., Minow, F., Sprock, J., Rissling, A., Sharp, R., ... & Braff, D. L. (2010). Electroencephalography (EEG) and event-related potentials (ERPs) with human participants. *Current protocols in neuroscience*, *52*(1), 6-25. doi: 10.1002/0471142301.ns0625s52

Mun, S., Whang, M., Park, S., & Park, M.C. (2017). Effects of mental workload on involuntary attention: A somatosensory ERP study. *Neuropsychologia*, *106*, 7–20. doi: 10.1016/j.neuropsychologia.2017.08.021

Näätänen, R. & Picton, T. W. (1987). The N1 wave of the human electric and magnetic response to sound: A review and an analysis of the component structure. *Psychophysiology*, 24, 375-425. doi: 10.1111/j.1469-8986.1987.tb00311.x

Park, J. L., Fairweather, M. M., & Donaldson, D. I. (2015). Making the case for mobile cognition: EEG and sports performance. *Neuroscience & Biobehavioral Reviews*, *52*, 117-130. doi: 10.1016/j.neubiorev.2015.02.014

Picton, T. W., Ouellette, J. E. A. N., Hamel, G., & Smith, A. D. (1979). Brainstem evoked potentials to tone-pips in

notched noise. *J Otolaryngol*, *8*(4), 289-314.
Pivik, R. T., Broughton, R. J., Coppola, R., Davidson, R. J., Fox, N., & Nuwer, M. R. (1993). Guidelines for the recording and quantitative analysis of electroencephalographic activity in research contexts. *Psychophysiology*, 30, 547-558. doi: 10.1111/j.1469-8986.1993.tb02081.x
Salazar, W., Landers, D. M., Petruzzello, S. J., Han, M., Crews, D. J., & Kubitz, K. A. (1990). Hemispheric asymmetry, cardiac response, and performance in elite archers. *Research quarterly for exercise and sport*, *61*(4), 351-359. doi: 10.1080/02701367.1990.10607499
Simsek, D., Cerrah, A. O., Ertan, H., & Soylu, R. A. (2018). Muscular coordination of movements associated with arrow release in archery. *South African Journal for Research in Sport, Physical Education and Recreation*, *40*(1), 141-155
Soylu, A. R., Ertan, H., Korkusuz, F. (2006). Archery Performance Level and Repeatability of Event-Related EMG. *Human Movement Science*, 25, 767-774. doi:10.1016/j.humov.2006.05.002
Sur, S., & Sinha, V. K. (2009). Event-related potential: An overview. *Industrial psychiatry journal*, *18*(1), 70. doi: 10.4103/0972-6748.57865
Volosin, M., Grimm, S., & Horváth, J. (2016). Exploiting temporal predictability: Event-related potential correlates of task-supportive temporal cue processing in auditory distraction. *Brain research*, *1639*, 120-131. doi: 10.1016/j.brainres.2016.02.044
Wilkinson, R. T., Morlock, H. C., & Williams, H. L. (1966). Evoked cortical response during vigilance. *Psychonomic Science*, *4*(6), 221-222. doi: 10.3758/BF03342260
Woodman, G. F. (2010). A brief introduction to the use of event-related potentials in studies of perception and attention. *Attention, Perception, & Psychophysics*, *72*(8), 2031-2046. doi: 10.3758/BF03196680
Woods D. L. (1995). The component structure of the N1 wave of the human auditory evoked potential. Perspectives of Event-Related Potentials Research (EEG Suppl. 44) Editors: G. Karmos, M. Molnar, V. Csepc, I. Cziglcr and J. E. Dcsmcdt; Elsevier Science B. V.
World Archery Federation (WA) (2019). *Constitutions and rules*. Available online at https://worldarchery.org/rulebook/article/877 (Accessed 22nd of February, 2019).

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ORIGINAL SCIENTIFIC PAPER

The Attack in Volleyball from the Perspective of Social Network Analysis: Refining Match Analysis through Interconnectivity and Composite of Variables

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Abstract

This study aimed to develop an instrument for analysing the attack in high-level volleyball considering the refined variables adjacent to the attack action, the interconnection between direct and indirect actions, the impact of the previous action, and the formation of composite variables. The game complexes were approached as interacting subsystems. The primary goal was to understand the influence of game actions adjacent to the attack. Three matches of a National Women's 1st Division 2018/2019 (nine sets, 415 plays) were analysed, considering all game complexes (except attack coverage due to reduced occurrence). An Eigenvector Centrality network with 420 nodes and 7367 edges was created. The networks showed that ideal setting conditions, and strong attacks by the outside and opposite hitters without having received a perfect ball, were central in side-out. In transition, we highlight ideal setting conditions, preferences of the outside hitter, quick attacks in Z4, and high balls in Z2. This study is distinct because it considers different aspects related to the systemic review of the game by using composite variables and the actions prior to the attack. Of these results, we highlight that players attacked with slower tempos for the double action of receive-attack, and these were either preferably directed to the parallel or explored the block. Moreover, for the double defence-attack actions, attackers sought the soft spike in Z2, Z4, and Z8; and when two consecutive individual errors occurred, the players did not err but instead continued to attack to force the opponent's error.

Keywords: *performance analysis, game analysis, social network analysis, eigenvector centrality, attack, volleyball*

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Introduction

The study and development of team sports can be conceptualized at three levels with performance analysis as an umbrella concept, match analysis as a sub-genre within performance, and Social Network Analysis as a specific tool for conducting match analysis. Performance analysis refers to the interpretation of different performance indicators for the optimization of the training process and matches (Hughes, 2004). One of

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its primary objectives is to provide feedback to athletes and coaches to support decision making (Hodges & Franks, 2008). Match analysis, the process of recording individual game actions within a play context (Hughes & Franks, 2008), is one possible application of performance analysis. Match analysis has contributed positively to volleyball research on the influence of reception quality, attack tempo and block type on attack efficacy (Costa, Afonso, Barbosa, Coutinho, & Mesquita, 2014); on the performance links between game actions and the final ranking in the league (Conejero, Claver, González-Silva, Fernández-Echeverría, & Moreno, 2017); and on the creation of references to understand team performance in certain game actions by means of a longitudinal study (Drikos & Tsoukos, 2018).

Social Network Analysis has established itself as a powerful tool for match analysis, particularly when focusing on behaviour and the relationships between the players involved in the network (captured by nodes and connected by edges; Borgatti, 2005; Wäsche, Dickson, Woll, & Brandes, 2017). Studies have mostly focused on match analysis with the nodes centred on the players (Ribeiro, Silva, Duarte, Davids, & Garganta, 2017). Thus far, the most common measure has been degree centrality (e.g., Gama et al., 2014; McLean, Salmon, Gorman, Stevens, & Solomon, 2018), which calculates the number of direct connections between nodes (Borgatti, 2005). However, recent research in volleyball (Laporta, Afonso, and Mesquita, 2018a; 2018b; Laporta, Afonso, Valongo, and Mesquita, 2019) has applied Eigenvector Centrality, which considers the value of a node as the weighted sum of both direct and indirect connections (Bonacich, 2007). Moreover, such studies have begun to consider game actions, and not only players, as nodes (e.g., Hurst et al., 2016; Laporta et al., 2019).

These studies made significant contributions to the literature, but most had limitations concerning the way in which attack actions were analysed. These limitations included a limited consideration of game actions without the ball, using tools with relatively limited levels of efficacy and, most notably, the analysis of each action without considering the outcome of previous attack actions. We aim to overcome these limitations to give a greater systematic overview of the game. Moreover, we also aim to address the limitation of conducting match analysis via interconnectivity and compositive variables. For match analysis to be representative of the game, interactions between current and previous actions, and the effects of prior efficacy on current efficacy, should be considered.

In sum, the overarching goal of the current study was to develop a more comprehensive analysis of volleyball game actions. We aimed to meet this goal by testing a more refined instrument for analysing attack actions. This instrument considers the interconnection between direct and indirect actions, the influence of the previous action, and the formation of composite variables. Thus, because it was designed to consider the dynamics and complexity of the game, we anticipated this instrument would represent a fundamental tool aligned with the potential of Social Network Analysis.

Methods

Sample

We analysed three matches, corresponding to nine sets and 415 plays, from a National Women's 1st Division (2018/2019). All complexes were analysed. More specifically, we analysed the node corresponding to the attack action and its relations with other nodes (other game actions).

Variables

The variables were classified as either simple or composite (see Table 1). Volleyball is structured in seven interdependent game complexes with distinct game flow characteristics (Loureiro et al., 2017; Hurst et al., 2016): complex 0 (K0) or serve, Complex I (KI) or side-out, Complex II (KII) or side-out transition, Complex III (KIII) or transition, Complex IV (KIV) or attack coverage, Complex V (KV) or freeball, and Complex VI (KVI) or downball. We chose not to analyse KIV because of its low occurrence, with only 3.89% of ball possession in men and 4.1% in women (Laporta, 2014).

The simple variables analysed were server starting position (Data Volley, 2018; Fernández-Echeverría et al., 2017), type of serve (Afonso, Esteves, Araújo, Thomas, & Mesquita, 2012), serve relationship with the positioning of the screening, serve efficacy, first contact zone, type of reception contact, the function of the player who received or attacked (outside hitter (OH), libero (LB), middle-blocker (MB), opposite (OPP), setter (ST)) (adapted from Afonso et al., 2012), ideal vs non-ideal setting conditions (Hurst et al., 2016; Laporta et al., 2018b), availability of the middle-blocker (adapted from Afonso, Mesquita, Marcelino, & Silva, 2010), and the combination of attack with tempo (adapted from Afonso et al., 2010; Data Volley, 2018).

We also studied where the attacker establishes contact with the ball (the need to clarify the various attack tempos across the nine zones resulted in 20 combinations), attack trajectories (Data Volley, 2018), type of attack (based on the position of the attacker and attack efficacy; Data Volley, 2018), the behaviour of the block (e.g., its starting points; adapted from Afonso, Laporta, and Mesquita, 2017), behaviour prior to the setter (adapted from Afonso & Mesquita, 2011), block opposition being without blocks, and efficacy of the block (Data Volley, 2018). Composite variables were also coded: attack without/after receiving, attack after two consecutive errors, and attack after defence/undefended attack.

Data collection, procedures and reliability

First, a spreadsheet was built in Microsoft Excel 2017 with macro buttons to catalogue the necessary codes into the appropriate cells. The data collection procedures were then conducted, and intra-observer reliability evaluated using 10% of the total sample (cf. Fleiss, Levin, & Paik, 2013). For intra-observation reliability, Cohen's Kappa values ranged from .959 to .999. For inter-observation reliability, these values ranged from .774 to .997. Thus, all variables were greater than the threshold of 0.75 proposed by Tabachnick and Fidell (2007).

Next, data were analysed using SPSS for Windows (version 25, IBM®, USA), which included a verification of data quality followed by descriptive analysis and the production of cross tables. The software Gephi© was used to calculate the connections and their weights using Eigenvector Centrality. Node sizes were manipulated using the intrinsic units given by the software, set to vary between 300 and 1500 to ensure proper visual contrast.

Results

A global network of intra- and inter-complex interactions was established using Eigenvector Centrality to provide a map of interactions (Figure 1). To create an interactive network, the complexes were separated by colour: K0 (yellow), KI (red), KII (grey), KIII (green), KV (purple) and KVI (pink).

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Table 1. Study Variables

Variables	Category/Description	Complex	Simple/ Composite	New
Server starting position (SSP)	Zones (court order): 5 | 7 | 6 | 9 | 1 Zone1 (from the right sideline to 1.8m inside). Zone 9 (from the 1.8m on the right side to the centreline on the left). Zone 6 (most central parcel - from 3.6m to 5.4m). Zone 7 (from the 1.8m on the left side to the centreline on the right). Zone 5 (from the left sideline to 1.8m inside). Note, it is considered a fault if the player steps into the final line.	K0	Simple	
Type of serve (S)	Overhand serve (with displacement and explosive jump and with rotation of the ball) (OVHS). Float (no jump - serve in support) (FLT). Jump-float (no ball rotation and uniform trajectory) (JFLT).	K0	Simple	
Block screening (BC)	Sectorized in Z4 (CBZ4): from the left side line (near the net) to 3 metres indoor. Centralized in Z3 (CBZ3): from 3 to 6 metres (near the net). Sectorized in Z2 (CBZ2): from the right side line (near the net) to 3 metres indoor. BCZ4 | BCZ3 | BCZ2	K0	Simple	
Serve efficacy (SE)	# Ace (direct point). + Positive (it generates a perfect pass that allows the opponents' setter to set all combinations). ! Exclamatory (serve bulk but recovered). - Negative (the opponent receives the ball # and can attack in any way). / Poor (the reception of the opponent is poor. The ball is sent directly in the other court or cannot be attacked). = Error (point to opposition - net ball, out, foot foul).	K0	Simple	
Block starting points (BSP)	Open (BSPO) (3 network players are close to each other [1 metre], in the centre of the network). Closed (BSPC) (3 players on the block, are far away in the net, i.e., one in the centre of the network and the other two separated about 2m). Mixed to the right (BSPMR) (two of the players – middle-blocker and opposite – are close with about 1m – in Z2 and another (outside hitter) away from these, about 2 to 3m - in Z4 – i.e., to block the fast set of the middle-blocker). Mixed to the left (BSPML) (two of the players – central and outside hitter – are close to each other in 1m – in Z4 and another (opposite) away from these, about 2 to 3m - in Z2). No exist block starting points (NO).	K0	Simple	✓
Reception line (RL)	RL 3: 3 receivers. RL 2+1: 2 priority receivers (4.5 metres each) and 1 receiver with less reception space (only 1 metre). RL 4: 4 receivers.	KI	Simple	
1st contact zone (FCZ)	Zone 1 to 9.	KI to KVI	Simple	
Type of 1st contact (TFC)	R # (ball in hand for perfect setting, all combinations can be made – 4/5 valid options). R+ (reception within 3 metres with at least 3 attack points without all combinations). R+KM (Sectorized reception for Z2). R+KP (Sectored reception for Z4). R+K0 (Sectorized reception for Z8). R! (when reception is neither negative nor positive, usually when you can force the use of the middle-blocker). R- (reception outside 3 metres, with 3 valid options). R/ (direct reception to the opposition court). R= (error - direct point for the opposition).	KI	Simple	✓
Reception player function (RPJ)	Right side hitter (RH). Outside hitter (OH). Libero (Lb). Middle-blocker (MB). Opposite (OPP). Setter (ST).	KI	Simple	
Setting conditions (SC)	A (all attack options available). B (fast game, but no combined moves available). C (only available attackers from the ends or background court). NO (no exist).	KI to KVI	Simple	

(***continued on next pages***)

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Variables	Category/Description						Complex	Simple/Composite	New
Availability of the middle-blocker (AMB)	Quick attack on the front (in front of and near the setter) (QAF). Attack away at the front (in front and away from the setter) (AAF).	Quick attack on the back (on the back and close to the setter) (QAB). Attack away on the back (on the back and away from the setter) (AAB). NO (no exist).					KI	Simple	✓
Function of the attack player (ATAC)	Outside hitter (ATACOH). Middle-blocker (ATACMB). Opposite (ATACOP).	Setter (ATACST). NO (no exist).					KI to KVI	Simple	
Attack Zone/ Combination (AZ/Comb)	V4 X4	X7 X9	CE XT	CF X3 PR	CC C1 PP	CH X2 V2	KI to KVI		✓
		XR	XP		XB	X1 V1			
	V4 – high tempo in Z4 – (from 1.5m from the left line). X4 – fast tempo in Z4 – (from 1.5m from the left line).	X9 – inside attack in Z4 – (1.5m inside, from V4). X7 – tempo away at the front, of the middle-blocker – (1.5m inside, from V4). XR – pipe in Z8/Z5 – (1.8m inside, from XP).	CE – quick attack, slightly, near the setter, the middle-blocker – (1.5m inside, from X7). XT – combined play between middle-blocker and right side hitter – (1m inside, from X7). XP – centrality pipe attack on Z8 – (1.8m inside, from V1).	CF – quick attack at the front and next to the setter, of the middle-blocker – (1.5m inside, from CE). X3 – combined move between middle-blocker and opposite – (1m inside, from CE). PR – penalty.	CC – quick attack on the back and next to the setter – (1.5m outside, from CF). C1 - inside attack in Z2 – (1.5m outside, from CF). PP – 2nd touch. XB – pipe in Z8/ Z1 – (1.8m inside, from XR).	CH – quick and tense attack of the middle-blocker, away from the setter – (1.5m abroad, from CC). X2 – fast tempo in Z2 – (1.5m abroad, from CC). V2 – high tempo in Z2 – (1.5m abroad, from CC). X1 – fast tempo in Z1 – (from the right line to 1.8m inside). V1 – high tempo in Z1 - (from the right line to 1.8m inside). NO (no exist combination).		Simple	
Attack trajectories zones (ATZ)	Zone 1 to 9. NO (no exist).						KI to KVI	Simple	
Type of attack, based on the attacker's position (TpA)	Strong attack	Parallel (Z9/ Z1) – SAL. Paragonal/between blockers (Z6/Z8) – SAP. Small crosscourt (SASD).	Intermediate crosscourt (SAID). Great crosscourt (SAGD).				KI to KVI	Simple	✓
	Directed attack (Tip)	Line (Z9/ Z1) – DAL. Paragonal/between blockers (Z6/Z8) – DAP. Small crosscourt (DASD).	Intermediate crosscourt (DAID). Great crosscourt (DAGD).					Simple	✓
	Combined	Scissors (Z4/Z2) – ACSc. Up-and-down (Z4/Z2) – ACUaD.	Inside (Z4/Z2) – ACIn.					Simple	✓
	Soft spike	Z1 – AmoZ1.; Z2 – AmoZ2.; Z3 – AmoZ3. Z4 – AmoZ4.; Z5 – AmoZ5.; Z6 – AmoZ6.	Z7 – AmoZ7.; Z8 – AmoZ8.; Z9 – AmoZ9.					Simple	✓
	Exploration of the block	Block-ou side (BOS) – ball is reflected in the block to the sideline. Block-out Long (BOL) – ball is reflected to the back line. Block-out In (BOI) – do not confront the block: attack against it, to regain the ball again.						Simple	✓
	No exist type of attack (NO).							Simple	

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Attack efficacy (AE)	#	Perfect (point).			KI to KVI	Simple	
	+	Positive (attack that causes difficulty to opposing defence).					
	!	Exclamatory (attack bulk but recovered).					
	-	Negative (attack defended with ease).					
	/	Poor (attack blocked with kill and error).					
	=	Error (point to opposition).					
	NO	No exist efficacy.					
Results of previous actions (RPA)	Attack after receiving (AaR)		R# R+	R- R!	KI	Composite	✓
	Attack without receiving (AwR)		R# R+	R- R!	KI	Composite	✓
	Attack after 2 consecutive errors (Aa2Ce)		Individual (Ind) Collective (Cole)	No exist (AaENO)	KI to KVI	Composite	✓
	Attack after defending (AaD)		D # D +	D -	KI to KVI	Composite	✓
	Attack without defending (AwD)		D # D +	KI to KVI	KII, KIII, KV and KVI	Composite	✓
	AaesDNO		No attack occurred after reception/defence		KI to KVI	Composite	✓
Behaviour prior to the setting action (BPS)	This behaviour is intended for the middle-blocker player: Wait (BPSW): read and react strategy. Commit (BPSC) (strategy to anticipate the setter action):	BPSCFA – commit with faster attack closer. BPSJS – jump to the 2st touch or attack of the setter. Follow (BPSF) (strategy of following the opposing setter or the receipt or specific player):	BPSDZ4 – displacement from middle-blocker to Z4. BPSDZ2 – displacement from middle-blocker to Z2. BPSNO – no exist.		KII and KIII	Simple	✓
Block opposition (BOp)	Cohesive block: there is no space between blockers – the attacker cannot exploit their failures Open block: there's space between blockers. Broken block: the one in which the blocker arrives late, compensating with her arms diagonally.	No block; backs down to defend (B0BD). No block with merit of the opposition (B0WMO). Simple block, by choice (B1CH). Late simple block (B1L). Simple block with opposition merit (B1WMO).	Cohesive double block (B2C). Open double block (B2O). Double block broken without reaction to retreat and defend (B2WRRD). Cohesive triple block (B3C). Open/broken triple block (B3O). Impossible to analyse the block, i.e.: setter error (IAB). No block (BNO).		KII and KIII	Simple	✓
Block efficacy (BE)	#	Winning (direct point).			KII and KIII	Simple	
	+	Positive (the ball is touched and can be played again by the home team or point goes to the other team).					
	-	Poor (the opponent can play the ball again).					
	=	Error (hands out, net ball, ball in own side or opposite side).					
	NO	No block efficacy.					

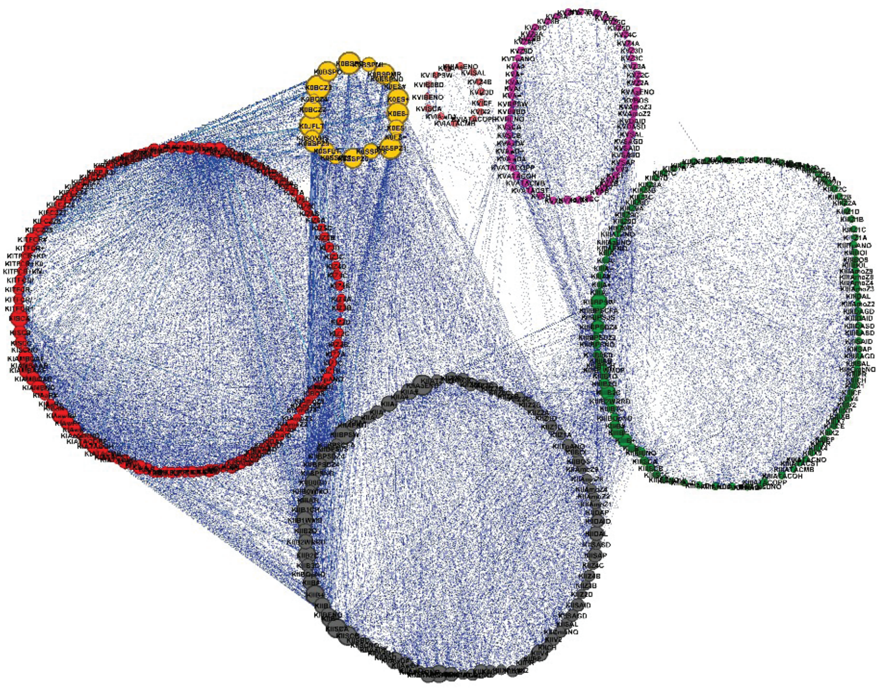

FIGURE 1. Network of the six complexes, with Eigenvector Centrality. Terminology: On each node, the codes are represented by the name of the complex, followed by the variable and its category. For example, KIIATACOH indicates that the action occurred in complex II, the variable in question was the function of the attacker, in this case, the outside hitter. The codes for the different variables: SSP – server starting position; S – type of serve; BC – screening block; BSP – block starting point; SE – serve efficacy; RL – reception line; RJP – player's reception function; FCZ – first contact zone; TFC – type of first contact; SC – setting conditions; AMB – availability of the middle-blocker; AAEWEX – attack after or without receive/defend; ATAC – attacker function; CMB – combination of attack; ATZ – attack trajectory zone; TpA – type of attack; AAE – attack after error; AE – attack efficacy; BPS – behaviour prior to the setting action; BOp – block opposition; BE – block efficacy. The EC values corresponding to each of the variables per complex are expressed in Table 2. In the K0, we highlight the values of; the jump-float serve, of serving from Z1, of the block screening in Z3, and serve efficacy being negative or positive. In KI, the most used was ideal setting conditions compared to the non-ideal. The most requested player in side-out was the OH, followed by OPP and MB. Concerning the attack, mostly it was without receiving but with the perfect ball followed by without receiving but with the positive ball. In situations in which the attacker received a perfect or positive ball and then attacked, the attackers sought to attack directed to the parallel, soft spike in Z9, or explored the block. Conversely, the attack tempo was fast on the Z4, slow on Z2 and the MB to attack CF and CH. In turn, the type of attack was either a strong attack on the parallel, a paragonal-directed attack, a great crosscourt or a crosscourt intermediate attack with a great efficacy of attack. As for the attack after two collective errors, the players sought the most controlled attack on the small crosscourt and the soft spike (Z3 and Z2).

The EC values for each of the variables per complex are presented in Table 2. In K0, we highlight the values for several variables: the jump-float serve, serving from Z1, the block screening in Z3, and serve efficacy being negative or positive. In KI, ideal setting conditions were more often used than non-ideal setting conditions. The most requested player in side-out was the OH, followed by OPP and MB. Most attacks happened without receiving and with a perfect ball. The second most common type of attacks happened without receiving and with a positive ball. In situations in which the attacker received a perfect or positive ball and then attacked, the attack was directed to the parallel, there was a soft spike in Z9, or the block was explored. The attack tempo was fast on the Z4, slow on Z2, and the MB tended to attack CF and CH. In turn, the type of attack was either a strong attack on the parallel, a paragon-directed attack, a great crosscourt, or a crosscourt intermediate attack with a high attack efficiency. In the case of the attack after two collective errors, the players sought the most controlled attack on the small crosscourt and the soft spike (Z3 and Z2).

In KII, the block was characterized by a wait, due to the conditions of the setter (mostly ideal), and the block opposition was double cohesive or individual. The most requested player was the OH. The most used attack tempos were the quick ball (in Z4), the high ball (in Z2), and CF from MB. As for the type of attack, it was used in the directed attack in line, as well as the strong attack in paragonal/between blockers and the strong attack in intermediate crosscourt. When players attacked after a positive defence, they looked for the soft spike in zones 2, 8, and 4. In KIII, the behaviour prior to the setting action was often waiting or to accompany to Z4, due to the higher occurrence of SCB followed by SCA and SCC, with block opposition being, mostly, double cohesive. The most requested attackers were the extremities (OH and OPP). The trajectories most performed by these attackers were the strong attack on the parallel, on the great crosscourt, and an attack tempo with the high ball. In KV, the ideal setting conditions predominated, followed by many attacks not preceded by perfect defences, and the most requested player was OH (who always had quick balls and sought to attack the parallel). The behaviour of the opposition block was always to wait. Finally, in KVI, due to its low occurrence (only twice), the ideal setting conditions and the attack of the MB were highlighted.

Discussion

In Social Network Analysis, interaction networks analyse the degree of connection and specificity in the different phases of a game, thus helping to identify the most influential critical

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actions in the flow of the game (Wäsche et al., 2017). Eigenvector Centrality weight both direct and indirect connections between nodes (Laporta et al., 2018a; 2018b). The current study aimed to create a more refined instrument for studying the attack in volleyball. This instrument considers the interconnection between direct and indirect action, the impact of the previous action, the use of composite variables, and adding a finer-graining filter to the analysis (i.e., by using specific variables surrounding the attack). Our data illustrate the complex dynamics of the game actions within each phase of the game and highlight the decisive role of each node, which aids in providing a more detailed perspective of the phenomena that occur within the interactive network.

Our results regarding specific variables are consistent with the literature (Costa et al., 2014; Laporta et al., 2018b) in that they show the most requested player in the attack was the outside hitter (followed by the opposite) and that the tempo of the attack included quick ball attacks at Z4 and high ball at Z2

Table 2. Eigenvector Centrality values for Complex

Complex	Variable	Eigenvector Centrality values
K0	Server starting position (SSP)	Z1 (0.83); Z5 (0.69); Z6 (0.60); Z7 (0.49); Z9 (0.60)
	Type of serve (S)	OVHS (0.44); FLT (0.58); JFLT (0.85)
	Block screening (BC)	Z2 (0.62); Z3 (0.87); Z4 (0.18)
	Block starting points (BSP)	BSPO (0.67); BSPC (0.78); BPSMR (0.72); BSPML (0.46); BSPNO (0.21)
	Serve efficacy (SE)	S# (0.20); S+ (0.73); S! (0.53); S- (0.77); S= (0.13)
KI	Reception line (RL)	3 (0.29); 2+1 (0.14); 4 (0.11)
	1st contact zone (FCZ)	Z1 (0.20); Z2 (0.15); Z3 (0.08); Z4 (0.10); Z5 (0.21); Z6 (0.25); Z7 (0.25); Z8 (0.25); Z9 (0.25)
	Type of 1st contact (TFC)	R# (0.32); R+ (0.27); R+KM (0.20); R+KP (0.20); R+K0 (0.19); R! (0.26); R- (0.24); R/ (0.20); R= (0.19)
	Reception player function (RPJ)	OH (0.25); RH (0.26); Lb (0.29); MB (0.14); OPP (0.09)
	Setting conditions (SC)	A (0.77); B (0.55); C (0.47); NO (0.07)
	Availability of the middle-blocker (AMB)	QAF (0.70); AAF (0.69); QAB (0.61); AAB (0.46); NO (0.54)
	Function of the attack player (ATAC)	OH (0.68); MB (0.57); OPP (0.64); ST (0.33); NO (0.13)
	Attack without receiving (AwR)	R# (0.71); R+ (0.60); R- (0.53)
	Attack after receiving (AaR)	R# (0.34); R+ (0.34); R- (0.30)
	Attack after 2 consecutive errors (Aa2E)	Colec (0.35); NO (0.80)
	Attack Zone/Combination (Cmb)	XP (0.34); V2 (0.49); X2 (0.34); PP (0.29); CF (0.37); CE (0.25); X9 (0.29); X7 (0.30); V4 (0.62); X4 (0.53); X1 (0.13); CC (0.22); XR (0.31); CH (0.39); V1 (0.30); N0 (0.12)
	Attack trajectories zones (ATZ)	Z1B (0.23); Z1C (0.24); Z2A (0.28); Z2B (0.41); Z2C (0.42); Z2D (0.31); Z3B (0.34); Z3C (0.25); Z3D (0.37); Z4A (0.33); Z4B (0.34); Z4C (0.36); Z4D (0.33); Z5B (0.37); Z5C (0.15); Z6A (0.17); Z6B (0.26); Z6C (0.34); Z6D (0.27); Z7A (0.26); Z7B (0.31); Z8A (0.24); Z8B (0.37); Z8C (0.34); Z8D (0.26); Z9A (0.26); Z9B (0.24); Z9C (0.45); Z9D (0.41)
	Type of attack (TpA)	SAL (0.52); SAP (0.57); SASD (0.30); SAID (0.48); SAGD (0.49); DAL (0.33); DAP (0.49); DASD (0.36); DAID (0.46); AmoZ2 (0.33); AmoZ3 (0.36); AmoZ4 (0.35); AmoZ8 (0.26); AmoZ9 (0.22); BOS (0.34); BOI (0.30); BOL (0.30); NO (0.32)
	Attack efficacy (AE)	A# (0.66); A+ (0.52); A/ (0.6447 A- (0.64); A! (0.29); A= (0.51); NO (0.18)
KII	Behaviour prior to the setting action (BPS)	BPSW (1); BPSCFA (0.48); BPSJS (0.28); BPSDZ4 (0.76); BPSDZ2 (0.57); BPSNO (0.13)
	Block opposition (B)	B0BD (0.69); B0WMO (0.30); B1CH (0.78); B1WMO (0.76); B2C (0.89); B2O (0.70); B2WRRD (0.53); B3C (0.61); IAB (0.24); OpBNO (0.13)
	Block efficacy (BE)	B# (0.64); B+ (0.95); B- (0.89); B= (0.86); EBNO (0.46)
	Setting conditions (SC)	A (0.75); B (0.75); C (0.35); NO (0.43)
	Function of the attack player (ATAC)	OH (0.58); MB (0.47); OPP (0.49); ST (0.25); NO (0.24)
	Attack without defending (AwD)	D# (0.59); D+ (0.54); D- (0.24)
	Attack after defending (AaD)	D# (0.21); D+ (0.31); D- (0.14)
	Attack after 2 consecutive errors (Aa2E)	NO (0.69)
	Attack Zone/Combination (Cmb)	XP (0.27); V2 (0.40); X2 (0.15); PP (0.25); CF (0.33); X7 (0.26); V4 (0.50); X4 (0.46); PR (0.19); CH (0.22); NO (0.23)
	Attack trajectories zones (ATZ)	Z1A (0.20); Z1C (0.28); Z1D (0.11); Z2A (0.15); Z2B (0.34); Z2C (0.32); Z2D (0.23); Z3B (0.20); Z4B (0.29); Z4C (0.25); Z6B (0.18); Z6C (0.24); Z7B (0.29); Z7C (0.31); Z8D (0.34); Z9C(0.35); Z9D (0.26); NO (0.23)
	Type of attack (TpA)	SAL (0.34); SALP (0.39); SASD (0.24); SAID (0.33); SAGD (0.32); DAL (0.40); DAP (0.27); DAID (0.33); AmoZ1 (0.15); AmoZ2 (0.28); AmoZ4 (0.20); AmoZ8 (0.22); AmoZ9 (0.19); BOS (0.29); BOI (0.24); NO (0.30)
	Attack efficacy (AE)	A# (0.52); A+ (0.38); A/ (0.29); A- (0.45); A! (0.28); A= (0.33); NO (0.21)

(***continued on next page***)

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Complex	Variable	Eigenvector Centrality values
KIII	Behaviour prior to the setting action (BPS)	BPSW (0.57); BPSCFA (0.13); BPSDZ4 (0.14); BPSDZ2 (0.33); BPSNO (0.15);
	Block opposition (B)	B0BD (0.29); B1CH (0.27); B1O (0.11); B1WMO (0.32); B2C (0.50); B2O (0.30); B2WRRD (0.21); B3C (0.20); IAB (0.01); OpBNO (0.05)
	Block efficacy (BE)	B# (0.24); B+ (0.41); B- (0.37); B= (0.44); EBNO (0.21)
	Setting conditions (SC)	A (0.13); B (0.13); C (0.08); NO (0.06)
	Function of the attack player (ATAC)	OH (0.07); MB (0.03); OPP (0.06); ST (0.01); NO (0.006)
	Attack without defending (AwD)	D# (0.06); D+ (0.05); D- (0.03)
	Attack after defending (AaD)	D# (0.02); D+ (0.009); D- (0.01)
	Attack after 2 consecutive errors (Aa2E)	NO (0.09)
	Attack Zone/Combination (Cmb)	XP (0.03); V2 (0.05); X2 (0.02); PP (0.02); CF (0.01); CE (0.01); X9 (0.02); X7 (0.02); V4 (0.05); X4 (0.03); PR (0.01); X1 (0.01); XB (0.01); XR (0.01); CH (0.01); NO (0.007)
	Attack trajectories zones (ATZ)	Z1A (0.01); Z1B (0.03); Z1C (0.03); Z1D (0.01); Z2A (0.02); Z2B (0.02); Z2C 0.02); Z2D (0.03); Z3A (0.03); Z3B (0.02); Z3C (0.01); Z3D (0.02); Z4A (0.01); Z4B (0.01); Z4C (0.02); Z4D (0.01); Z5B (0.02); Z5C (0.01); Z5D (0.01); Z6B (0.01); Z6C (0.02); Z6D (0.01); Z7A (0.02); Z7B (0.02); Z7C (0.01); Z7D (0.01); Z8A (0.03); Z8B (0.01); Z8C (0.02); Z8D (0.02); Z9A (0.03); Z9B (0.03); Z9C (0.03); Z9D (0.01); NO (0.001);
	Type of attack (TpA)	SAL (0.04); SAP (0.03); SASD (0.01); SAID (0.03); SAGD (0.04); DAL (0.03); DASD (0.03); DAID (0.02); DAGD (0.01); AmoZ2 (0.03); AmoZ3 (0.03); AmoZ4 (0.01); AmoZ8 (0.01); AmoZ9 (0.02); BOS (0.02); BOI (0.01); BOL (0.01); NO (0.02)
	Attack efficacy (AE)	A# (0.07); A+ (0.05); A/ (0.02); A- (0.04); A= (0.04); NO (0.007)
KV	Behaviour prior to the setting action (BPS)	BPSW (0.14)
	Block opposition (B)	B0BD (0.13)
	Block efficacy (BE)	NO (0.11)
	Setting conditions (SC)	A (0.19); B (0.07)
	Function of the attack player (ATAC)	OH (0.15); MB (0.11); OPP (0.10); ST (0.04)
	Attack without defending (AwD)	D# (0.18); D+ (0.06)
	Attack after defending (AaD)	D# (0.03)
	Attack after 2 consecutive errors (Aa2E)	NO (0.17)
	Attack Zone/Combination (Cmb)	CC (0.04); CF (0.08); PP (0.04); XB (0.04); X7 (0.04); X9 (0.03); X4 (0.11); V4 (0.09); V2 (0.05); X2 (0.12); CH (0.05)
	Attack trajectories zones (ATZ)	Z2A (0.03); Z2C (0.07); Z3A (0.07); Z3C (0.04); Z3D (0.04); Z4A (0.04); Z4C (0.08); Z5C (0.04); Z5D (0.04); Z6C (0.05); Z7A (0.08); Z7B (0.04); Z7D (0.06); Z8A (0.05); Z8B (0.05); Z8C (0.04); Z9A (0.05); Z9B (0.05); Z9C (0.05); Z9D (0.07)
	Type of attack (TpA)	SAL (0.13); DASD (0.04); BOS (0.04); SAGD (0.08); SAP (0.09); SASD (0.08); SAID (0.05); DAID (0.07); AmoZ2 (0.03); AmoZ3 (0.06); NO (0.04)
	Attack efficacy (AE)	A# (0.12); A+ (0.09); A/ (0.06); A- (0.07); A= (0.05)
KVI	Behaviour prior to the setting action (BPS)	BPSW (0.03)
	Block opposition (B)	B0BD (0.05)
	Block efficacy (BE)	NO (0.04)
	Setting conditions (SC)	A (0.04)
	Function of the attack player (ATAC)	MB (0.03); OPP (0.03)
	Attack without defending (AwD)	D# (0.03)
	Attack after 2 consecutive errors (Aa2E)	NO (0.03)
	Attack Zone/Combination (Cmb)	CF (0.03); X2 (0.03)
	Attack trajectories zones (ATZ)	Z3D (0.03); Z4D (0.03)
	Type of attack (TpA)	SAL (0.03)
	Attack efficacy (AE)	A- (0.03)

(perhaps due to the characteristics of the players; Marcelino, Afonso, Moraes, & Mesquita, 2014). Concerning the type of attack, it is worth noting the strong attack on the paragonal and parallel, the strong attack on the crosscourt (great and intermediate), the attack directed to the parallel and exploration of the block (side and long) because of the frequency of the block playing on wait and presenting between double and late cohesive or on setting merits. However, our results indicated that most of the game takes place between ideal setting conditions (i.e., A and B), which contradicts some previous research

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(Laporta et al., 2018b).

This study highlights the importance of conducting research using more refined variables (Laporta et al., 2019), with better definitions and categories; by using composite variables, thus considering interconnections between actions (direct and indirect) and the impact of the previous actions, it respects to a much greater extent the dynamic and complex systematic review of the game. The refinement of variables is fundamental to understanding the strength between nodes. In this study, the composite variables do not fragment the game and highlight the edges of the network (both in its direction and in its weight). Hence, it was demonstrated that coupled actions (e.g., receive-attack and defend-attack) statistically influence the setters' choices. Here, Eigenvector values reflected a centrality for the slowest attack tempos and trajectories attempting strong attacks in the parallel, soft spikes closer to the net, or exploration of the block (Afonso et al., 2012; Marcellin et al., 2014). It should be noted that seven new variables were created in this study.

The edges of our network clearly showed that when an attacker commits two consecutive attacking errors, they tried not to commit unforced errors in the third attempt, decreasing the assumed risk and allowing the continuity of the game. Moreover, our results revealed ideal setting conditions in KIII (SCB and SCA) as well as quick attack tempos. This finding directly contradicts Laporta et al. (2018b), who referred to non-ideal setting conditions (B and C) in KIII. Thus, our study adjusts to the idea of Marcelino et al. (2014) in which the strike depends on the interaction of several tactical-technical indicators that change the strategies of the teams, providing a systemic understanding of the game.

The large number of variables resulted in a very extensive instrument. Consequently, we will take the following steps for refinement. Firstly, we will aggregate the 36 subcategories for the attack trajectory zone (e.g., instead of Z9A-Z9D, assume solely as Z9) into nine variables. Second, the classification of the reception in KI will be reduced from nine categories to six. Third, when classifying the quality of the first touch, we found there was a direct relationship with the setting conditions (A, B or C), which in our view means it is possible to use only the classification of the setting conditions. Fourth, we will combine KVI with KV due to the rare occurrence of the first complex (twice). Finally, we will eliminate the availability variable of the MB in KI because it will have little influence on the attack.

This study has demonstrated that playing patterns are diverse and that play occurs in ideal setting conditions (B and A) in most complexes, which contradicts some of the results of Laporta et al. (2018b). Studies of this nature have practical implications for coaches, who should consider training in both ideal and non-ideal setting conditions and diversify attack patterns under various conditions. A substantial intra- and inter-complex relationship, which highlights the dynamics and complexity of the game actions, was also identified. Both KI and KII shared ideal setting conditions, outside hitter preference and parallel attack. For the KI-KII and KII-KIII interconnection, the behaviour of the block occurs most centrally on a waiting strategy and the attack tempo is quicker at one edge than at the other. This complex correlation is crucial for coaches to understand because it allows them to promote game scenarios based on previous actions or complexes (Paulo et al., 2018). This instrument has the potential to promote the use of Social Network Analysis in match analysis because it allows for a greater reading of the complexity and dynamics of the game (Passos et al., 2011; Ribeiro et al., 2017; Sasaki, Yamamoto, Miyao, Katsuta, & Kono, 2017), based on its systemic review. As for avenues to explore in future studies, Social Network Analysis and Eigenvector Centrality should be incorporated into research that addresses contextual variables (punctual difference, set/game moment and intra- and inter-set relationships).

In conclusion, the present study makes several significant contributions to volleyball research. It offers a more refined instrument than currently available in the literature, takes a more specific approach to attack variables, reinforces the importance of considering adjacent variables, and highlights the relevance of indirect connections. Hence, composite variables, interconnections between actions (direct and indirect), and the impact of the previous action are variables that consider the game flow and its interconnectivity. It is clear from the results that this instrument has the potential to advance both volleyball and the construction of instruments in other team sports. Finally, the study demonstrates that Social Network Analysis is a crucial tool for understanding the systemic and complex nature of the game.

References

Afonso, J., & Mesquita, I. (2011). Determinants of block cohesiveness and attack efficacy in high-level women's volleyball. *European Journal of Sport Science, 11*, 69–75. doi: 10.1080/17461391.2010.487114

Afonso, J., Esteves, F., Araújo, R., Thomas, L., & Mesquita, I. (2012). Tactical determinants of setting zone in elite men's volleyball. *Journal of Sports Science & Medicine*, *11*(1), 64–70.

Afonso, J., Laporta, L., & Mesquita, I. (2017). A importância de diferenciar o KII do KIII no voleibol feminino de alto nível. *Revista Portuguesa de Ciências do Desporto*, 140–147. doi: 10.5628/rpcd.17.S1A.140

Afonso, J., Mesquita, I., Marcelino, J., & Silva, J. (2010). Analysis of the setter's tactical action in high-performance women's volleyball. *Kinesiology,* 42(1), 82–89.

Bonacich, P. (2007). Some unique properties of eigenvector centrality. *Social Networks, 29*(4), 555–564.

Borgatti, S. (2005). Centrality and network flow. *Social Networks, 27*, 55–71. doi: 10.1016/j.socnet.2004.11.008

Conejero, M., Claver, F., González-Silva, J., Fernández-Echeverría, C., & Moreno, M. (2017). Analysis of performance in game actions in volleyball, according to the classification. *Revista Portuguesa de Ciências do Desporto, 17*, 196–204. doi: 10.5628/rpcd.17.S1A.196

Costa, G., Afonso, J., Barbosa, R., Coutinho, P., & Mesquita, I. (2014). Predictors of attack efficacy and attack type in high-level Brazilian women's volleyball. *Kinesiology*, 46, 242–248.

Drikos, S., & Tsoukos, A. (2018). Data benchmarking through a longitudinal study in high-level men's volleyball. *International Journal of Performance Analysis in Sport, 18*(3), 470–480. doi: 10.1080/24748668.2018.1493319

Fernández-Echeverría, C., Mesquita, I., González-Silva, J., Claver, F., & Perla Moreno, M. (2017). Match analysis within the coaching process: A critical tool to improve coach efficacy. *International Journal of Performance Analysis in Sport, 17*(1–2), 149–163. doi:

10.1080/24748668.2017.1304073

Fleiss, J. Levin, B., & Paik, M. (2013). *Statistical methods for rates and proportions*. John Willey & Sons.

Gama, J., Passos, P., Davids, K., Relvas, H., Ribeiro, J., Vaz, V., & Dias, G. (2014). Network analysis and intrateam activity in attacking phases of professional football. *International Journal of Performance Analysis in Sport*, 14(3), 692–708. doi: 10.1080/24748668.2014.11868752

Hodges, N., & Franks, I. (2008). The provision of information. In M. D. Hughes, and I. M. Franks (Eds.), *Essentials of performance analysis: An introduction* (pp.21–39). London: Routledge.

Hughes, M. (2004). Performance analysis: A 2004 perspective. *International Journal of Performance Analysis in Sports, 4*(1), 103–109. doi: 10.1080/24748668.2004.11868296

Hurst, M., Loureiro, M., Valongo, B., Laporta, L., Nikolaidis, P., & Afonso, J. (2016). Systemic mapping of high-level women's volleyball using social network analysis: The case of serve (K0), side-out (KI), side-out transition (KII) and transition (KIII). *International Journal of Performance Analysis in Sport, 16*(2), 695–710. doi: 10.1080/24748668.2016.11868917

Instruction Manual (2018). *Data Volley 4*, *Data Project*.

Laporta, L. (2014). *A cobertura de ataque em voleibol de alto nível feminino e masculino. Estruturas e regularidades emergentes do jogo* (Unpublished master dissertation). Portugal: Faculty of Sport, University of Porto.

Laporta, L., Afonso, J., & Mesquita, I. (2018a). The need for weighting indirect connections between game variables: Social network analysis and Eigenvector Centrality applied to high-level men's volleyball. *International Journal of Performance Analysis in Sport, 18*(6), 1067–1077. doi: 10.1080/24748668.2018.1553094

Laporta, L., Afonso, J., & Mesquita, I. (2018b). Interaction network analysis of the six game complexes in high-level volleyball through the use of Eigenvector Centrality. *PLoS ONE, 13*(9), e0203348. doi: 10.1371/journal.pone.0203348

Laporta, L., Afonso, J., Valongo, B., & Mesquita, I. (2019). Using social network analysis to assess play efficacy according to game patterns: A game-centred approach in high-level men's volleyball. *International Journal of Performance Analysis in Sport, 19*(5), 866–877. doi: 10.1080/24748668.2019.1669007

Loureiro, M., Hurst, M., Valongo, B., Nikolaidis, P., Laporta, L., & Afonso, J. (2017). A comprehensive mapping of high-level men's volleyball gameplay through social network analysis: Analysing serve, side-out, side-out transition and transition. *Montenegrin Journal of Sports Science and Medicine, 6*(2), 35–41. doi: 10.26773/mjssm.2017.09.005

Marcelino, R., Afonso, J., Moraes, J. C., & Mesquita, I. (2014). Determinants of attack players in high-level men's volleyball. *Kinesiology*, 46(2), 234–241.

McLean, S., Salmon, P. M., Gorman, A. D., Stevens, N. J., & Solomon, C. (2018). Full length article: A social network analysis of the goal scoring passing networks of the 2016 European football championships. *Human Movement Science,* 57, 400–408.

Mesquita, I., Palao, J. M., Marcelino, R., & Afonso, J. (2013). Performance analysis in indoor volleyball and beach volleyball. In T. McGarry, P. O Donoghue, & J. Sampaio (Eds.), *Handbook of sports performance analysis* (pp. 367–379). London: Routledge.

Passos, P., Davids, K., Araújo, D., Paz, N., Minguéns, J., & Mendes, J. (2011). Networks as a novel tool for studying team ball sports as complex social systems. *Journal of Science and Medicine in Sport*, 14(2), 170–176.

Paulo, A., Zaal, F. T. J. M., Seifert, L., Fonseca, S., & Araújo, D. (2018). Predicting volleyball serve-reception at group level. *Journal of Sports Sciences*, 36(22), 2621–2630. doi:10.1080/02640414.2018.1473098

Ribeiro, J., Silva, P., Duarte, R., Davids, K., & Garganta, J. (2017). Team sports performance analysed through the lens of social network theory: Implications for research and practice. *Sports Medicine, 47*(9), 1–8. doi: 10.1007/s40279-017-0695-1

Sasaki, K., Yamamoto, T., Miyao, M., Katsuta, T., & Kono, I. (2017). Network centrality analysis to determine the tactical leader of a sports team. *International Journal of Performance Analysis in Sport*, 17(6), 822–831.

Tabachnick, B., & Fidell, L. (2007). *Using multivariate statistics*. Boston: Pearson.

Wäsche, H., Dickson, G., Woll, A., & Brandes, U. (2017). Social network analysis in sport research: An emerging paradigm. *European Journal for Sport and Society, 14*(2), 138–165.

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ORIGINAL SCIENTIFIC PAPER

Hand-grip Strength is Correlated with Aerobic Capacity in Healthy Sedentary Young Females

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Abstract

Aerobic capacity, which is the maximum limit of the rate of oxygen consumption, is an important parameter in determining health-related physical fitness. This study was conducted to investigate the relationship between grip strength and aerobic capacity in healthy sedentary young females. Forty healthy, young, and sedentary females participated in the study (20.5±1.5 years). Body composition was assessed with the bioelectrical impedance method. The hand-grip strength of the individuals was measured with a hand-grip dynamometer. An indirect graded arm crank ergometer test was used to determine the peak oxygen uptake (VO_2peak). It was found that the grip strength was correlated with height (r=0.51, p=0.001), fat-free mass (r=0.45, p=0.004), and VO_2peak (r=0.36, p=0.023); however, there was no correlation between grip strength and body weight, body mass index, and body fat percentage (p>0.05). VO_2peak was negatively correlated with body fat percentage (r= -0.38, p=0.016) and body mass index (r= -0.30, p=0.045). The results showed that higher muscle strength and fat-free mass are related to higher aerobic capacity. It is considered that increasing muscle strength and fat-free mass as well as decreasing body fat may be an appropriate strategy to increase cardiorespiratory fitness.

Keywords: *oxygen consumption, hand strength, body composition*

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Introduction

Aerobic capacity is most commonly used to assess health-related physical fitness (Williams et al., 2007). Aerobic capacity (VO_2max) is the maximum limit of oxygen consumption, which is measured by a cardiopulmonary exercise tolerance test. It is also one of the main variables in exercise physiology and widely accepted as the best measure of an individual's cardiorespiratory fitness (Basset & Howley, 2000). In contrast, muscle strength is another parameter to assess health-related physical fitness (Williams et al., 2007). There are several methods to measure muscle strength; however, a hand-held dynamometer is very useful for this task. It was suggested that grip strength measurements could be used as a tool to rapidly acquire information about overall muscle strength in healthy individuals (Wind, et al., 2010). Furthermore, previous studies have reported that hand-grip strength is correlated with body composition, anthropometric characteristics (Ingrová, et al., 2017; Pizzigalli, et al., 2016), bone mineral density (Sutter et al., 2019), functional capacity (Braun et

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al., 2018), walking speed (Braun, et al., 2018), health and fitness scores (Kuh, et al., 2005), and physical activity level (Cooper, et al., 2017).

Aerobic capacity is related to many factors, such as age, gender, and physical activity level (Nazerian et al., 2016; Wilson & Tanaka, 2000). Furthermore, it is well-known that overall muscle strength is directly related to aerobic capacity (Burich, et al., 2015). It could be expected that hand-grip strength may be related to aerobic capacity, considering the relationship between hand-grip strength and overall muscle strength. Indeed, the relationship between hand-grip strength and aerobic capacity has been investigated by a few studies (Kim et al., 2018; Moberg, et al., 2017; Thomaes, et al., 2012; Wallymahmed, et al., 2007); however, these studies were conducted in a geriatric population or in those with different pathological conditions (type I diabetes, cancer, or cardiovascular disease, etc.). The relationship between hand-grip strength and aerobic capacity may be different in young individuals, considering the loss of muscle mass or changes in neuromuscular interaction in the geriatric population or in those with different pathological conditions. Therefore, the purpose of this study was to investigate the relationship between hand-grip strength and aerobic capacity in healthy young sedentary females. We hypothesized that hand-grip strength would be related to aerobic capacity in healthy young sedentary females.

Methods

Subjects

The study included 40 healthy sedentary young females between the ages of 19 and 25 (20.5±1.5 years). Participants who had not been exercising regularly for at least 6 months prior to the study were accepted as sedentary individuals. Individuals were excluded if they had any upper extremity problems that may impair cycling ability and also had a history of any active infection, peripheral vascular disease, metabolic disease, and other autoimmune, chronic systemic inflammatory disease, malignancy, presence of serious pulmonary, cardiac, or endocrine diseases, which may affect the outcomes of the exercise test. The ethics approval was obtained from the Non-Invasive Clinical Research Ethics Board of the Mersin University (Protocol Number: 2019/434) and written informed consent was obtained from each participant.

Anthropometric measurements

Height was measured with a stadiometer with subjects standing in bare feet. Body composition parameters (body weight, body mass index (BMI), fat-free mass (FFM), and body fat (%)) were assessed with the bioelectrical impedance method, which was reported to be valid and reliable, using a Tanita BC-418MA Segmental Body Composition Analyzer (Tanita Corporation, Tokyo, Japan).

Hand-grip strength

Hand-grip strength was measured with a hand-grip dynamometer (Baseline, Fabrication Enterprises Enc, Inc, NY, USA). Hand-grip strength measurements were performed on the dominant hand, which was determined by asking the subjects to write something. Prior to the test, the device was set for average hand size. Similar to previous studies (Pizzigalli, et al., 2016; Wind, et al., 2010), hand-grip strength measurements were performed in a sitting position, upright against the back of a chair with the feet flat on the floor and the shoulder adducted and neutrally rotated, elbow flexed to 90° (Figure 1). The subjects were instructed to squeeze the device "as hard as possible", and verbal encouragement was given during each trial. The device measures the value of hand-grip strength in kilogram (kg). The hand-grip strength was calculated by taking the average of three successive measurements.

FIGURE 1. Measurement of hand-grip strength

Arm Crank Test

The participants performed a maximal exercise test on an arm crank ergometer (Monark 831 E; Monark Exercise AB, Varberg, Sweden). The metabolic analyser was calibrated before each test with known gas concentrations (Quark CPET, COSMED, Rome, Italy). Heart rate (HR) was recorded throughout the graded maximal exercise test using a transmitter belt (Wireless HR Monitor, COSMED).

The subjects were asked to fill out a Physical Activity Readiness Questionnaire (PAR-Q), which screens health

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problems that may occur during exercise tests (Thomas, et al., 1992). All participants were instructed to refrain from vigorous exercise, caffeine, tobacco, and alcohol on the day before and on the test day and be ready at the laboratory after three (3) hours of fasting. After a 15-minute rest period, the participants performed unloaded cranking for 2 min. This period was followed by the first stage that began with 20 W and then increased by 6 W every minute until they were unable to maintain the specified wok rate (Mitropoulos, et al., 2017). Throughout the exercise test, they were verbally encouraged to continue the test until exhaustion. The rating of perceived exertion (RPE) was recorded by Borg's scale (6–20 points) at the end of each stage (Borg, 1982). All measured variables and HR data were averaged every 15 s. If VO_2max was not achieved during the test, the peak oxygen consumption (VO_2peak) was used instead.

Statistics

The sample size was calculated using the SPSS Sample Power 3.0 software (IBM Corporation, Armonk, NY, USA). The calculations were based on an expected correlation coefficient value of 0.50, followed by an alpha level of 0.5, and the desired power level of 80%. The estimated sample size was calculated to be at least 29 participants (Browner et al., 2007).

Statistical analyses were performed using software (SPSS version 22, IBM Corporation, Armonk, NY, USA). Analytical (Shapiro-Wilk's/Kolmogorov-Smirnov test) and visual methods (probability plots and histograms) were performed to determine whether or not the assessed parameters were normally distributed. Descriptive analyses are presented using mean and standard deviation (SD). The correlation between the assessed parameters was determined using the Pearson test. An overall 5% Type 1 error level was accepted for inter-statistical significance.

Results

The characteristics of the subjects and the results of the measurements are presented in Table 1. The right hand was the dominant side in all subjects.

Table 1. Mean (± SD), Minimum and Maximum Values of Demographic Data and Assessed Parameters

Parameters	Mean ± SD	Minimum-Maximum
Age (years)	20.5±1.5	19.0–25.0
Height (m)	1.61±0.05	1.51–1.72
Body weight (kg)	56.5±7.9	45.0–73.3
Body mass index (kg/cm²)	21.6±3.0	16.8–29.1
Body fat (%)	26.3±5.8	16.6–36.7
Fat free mass (kg)	41.5±3.8	35.4–49.1
VO_{2peak} (ml/kg/min)	22.4±2.7	17.9–28.0
Handgrip strength (kg)	25.9±4.0	18.0–33.0
Peak heart rate (beat/min)	171.9±6.7	162.0–191.0
Respiratory quotient	1.1±0.1	0.9–1.2
Rating of perceived exertion	18.3±1.0	17.0–20.0

Note. VO_{2peak}: peak oxygen consumption.

Dominant grip strength was positively correlated with height (r=0.51, p=0.001), FFM (r=0.45, p=0.004), and VO_2peak (r=0.36, p=0.023); however, there was no correlation between grip strength age, body weight, BMI, and body fat percentage (p>0.05) (Table 2). VO_2peak was negatively correlated with body fat (%) (r=-0.38, p=0.016) and body mass index (r=-0.30, p=0.045); however, VO_2peak was positively correlated with RPE (r=0.40, p=0.011) (Table 2) (Figure 2).

Table 2. Correlation Analysis Results among Handgrip Strength, Demographic Data, and Maximal Exercise Test Parameters

Parameters	Height	Body Weight	BMI	Body fat	FFM	VO_{2peak}	Handgrip Strength	HR_{peak}	RQ	RPE
Age (years)	0.14	-0.19	-0.29	-0.06	-0.20	0.04	0.09	0.08	-0.08	-0.11
Height (m)		0.31	-0.21	-0.01	0.52†	0.11	0.51†	-0.01	0.01	-0.01
Body weight (kg)			0.84†	0.78†	0.83†	-0.23	0.26	0.00	-0.01	0.04
Body mass index (kg/m²)				0.85†	0.51†	-0.30*	-0.06	0.05	0.04	0.01
Body fat (%)					0.30	-0.41*	-0.02	0.20	0.05	0.01
Fat-free mass (kg)						0.09	0.46†	0.09	-0.12	0.06
VO_{2peak} (ml/kg/min)							0.34*	0.05	-0.25	0.40*
Hand-grip strength (kg)								0.17	0.06	0.19
Heart rate (beat/min)									0.02	-0.09
Rating of perceived exertion										-0.26

Note. *p<0.05, †p<0.001. BMI: body mass index; FFM: fat-free mass; VO_{2peak}: peak oxygen consumption; HR_{peak}: peak heart rate; RQ: respiratory quotient; RPE: rating of perceived exertion.

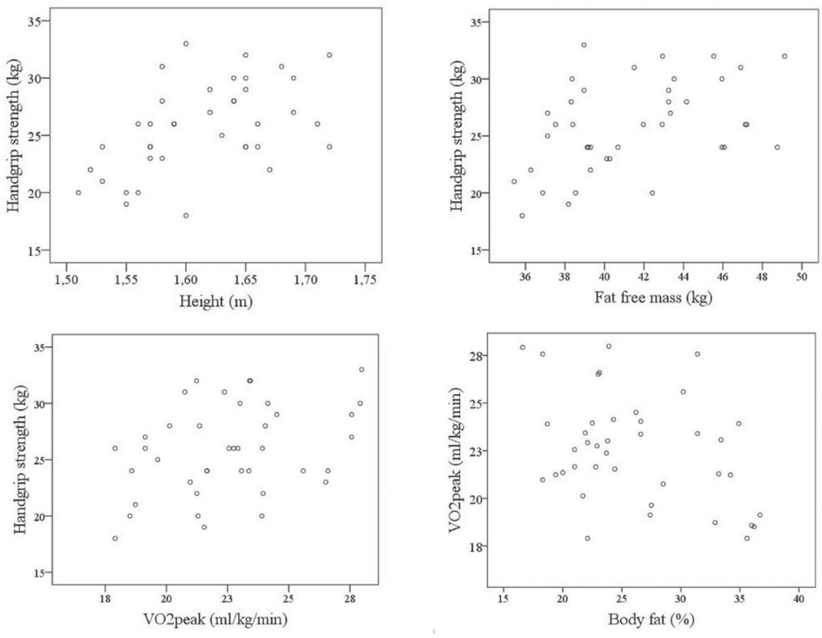

FIGURE 2. Scatterplots of correlation analysis of assessed parameters. VO2peak- peak oxygen consumption.

Discussion

The purpose of the present study was to investigate the relationship between hand-grip strength and aerobic capacity. To the best of our knowledge, this is the first study investigating the relationship between hand-grip strength and aerobic capacity in young, healthy individuals. In line with our hypothesis, it was found that hand-grip strength was correlated with VO_2peak in healthy sedentary young women. Similar to our results, Wallymahmed et al. (2007) revealed that aerobic capacity was adequately (i.e., fairly well) correlated with hand-grip strength ($r=0.27$, $p<0.01$) in patients with Type I diabetes. Furthermore, Thomas, Reading, and Shephard (2012) found a fair-to-moderate correlation between hand-grip strength VO_2peak in CAD patients.

Furthermore, it was reported that resistance exercise intervention could increase aerobic capacity and muscle strength (Giuliano, et al., 2017; Scribbans, et al., 2016; McRae et al., 2012). The results of the present study support the assertion that grip strength is related to aerobic capacity; however, the relationships were relatively low ($r=0.34$). The results are reasonable, considering the complex process of aerobic capacity. R-squared, which explains the strength of the relationship between the assessed parameters, shows that variance in hand-grip strength explained the variance in VO_2^{peak} in just up to 12% of the assessed individuals (Cohen, et al., 2003). In this study, healthy, young, and sedentary females with normal body weight were recruited to obtain a homogeneous study group, but many factors affect aerobic capacity; these factors were not controlled in the present study (e.g., cardiac output or arterial-venous oxygen difference, pulmonary system, etc.) (Bassett & Howley, 2000).

Some studies investigate the relationships between hand-grip strength and the other physiological and physical fitness parameters. For example, Sutter et al. (2019) reported that hand-grip strength was fairly correlated with bone mineral density ($r=0.28–0.35$, $p<0.05$). Matsudo and Rezende (2015) demonstrated that hand-grip strength was correlated with the vertical jump test ($R^2=0.20$; $p=0.001$) and speed (in metres per second: $R^2=0.47$; $p=0.001$) in children and adolescents. Peterson et al. (2019) reported that there was a moderate-to-strong correlation between hand-grip strength and respiratory muscle strength ($r=0.54–0.74$, $p<0.05$). Girard and Millet (2009) also demonstrated that hand-grip strength was significantly correlated with tennis performance in competitive teenage players. There have been many attempts to investigate the relationships between hand-grip strength and physical fitness parameters because hand-grip strength measurement is low-cost, easy, and quick, and determining the hand-grip strength may be used to predict other physical fitness parameters. Prior to this study, we hypothesized that hand-grip strength would be strongly correlated with aerobic capacity, and hand-grip strength measurement might assist in predicting aerobic capacity. However, the results obtained do not support this hypothesis.

Another critical finding of the present study is that an increase in body fat percentage and BMI was negatively correlated with a decrease in VO_{2peak}; however, the fat-free mass percentage was positively correlated with hand-grip strength. The results suggest that an increase in body fat percentage may cause a decrease in aerobic capacity. Similar to our results, Durkalec-Michalski et al. (2019) revealed that body mass and fat-free mass significantly contributed to the prediction of VO_2max in highly trained male rowers. Furthermore, Badaam, Deore, and Shazia (2015) found that overweight young females had lower aerobic capacity compared to normal-weight young females. In contrast, Muollo et al. (2019) reported that a decrease in body fat via an exercise and diet programme could cause an increase in aerobic power in obese individuals. Similar to previous studies, our results also support that decreasing body fat percentage or weight loss may be an appropriate strategy to increase aerobic power.

The study has some limitations. First, it was conducted with healthy, young, and sedentary females; however, the relationships between hand-grip strength and aerobic capacity may be different in different populations, such as males, geriatric patients, or athletes. Second, hand-grip strength was used

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in this study to investigate the relationships between muscle strength and aerobic capacity. Assessing the strength of different muscles in addition to hand-grip strength could have yielded more information about the relationship between muscle strength and aerobic capacity.

In conclusion, the results of the present study show that hand-grip strength was positively correlated with aerobic capacity; however, body mass index and body fat percentage were negatively correlated with aerobic capacity in healthy young sedentary females. Our results support the assertion that increasing the grip strength or decreasing body mass and body fat percentage may be an appropriate strategy to increase aerobic power.

References

Badaam, K., Deore, D., & Shazia, S. (2015). Assessment of aerobic capacity in overweight young females: A cross-sectional study. *International Journal of Applied and Basic Medical Research*, 5(1), 18-20. doi: 10.4103/2229-516X.149224

Basset, D. R., & Howley, E. T. (2000). Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Medicine and Science in Sports and Exercise,* 32 (1), 70–84. doi: 0195-9131/00/3201-0070/0

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise,* 14(5), 377-381. doi: 10.1249/00005768-198205000-00012

Braun, A. K., Hess, M. E., Ibarra-Moreno, U., Salvatore, M. D., & Saunders, N. W. (2018). Hand-grip strength as a screening assessment for functional limitations. *Physical Therapy and Rehabilitation*, 5, 16. doi: 10.7243/2055-2386-5-16

Burich, R., Teljigović, S., Boyle, E., & Sjøgaard, G. (2015). Aerobic training alone or combined with strength training affects fitness in elderly: Randomized trial. *European Journal of Sport Science,* 15(8), 773–783. doi: 10.1080/17461391.2015.1060262

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2003). *Applied multiple regression/correlation analysis for the behavioral sciences*. Mahwah, NJ: Lawrence Erlbaum Associates.

Cooper, A., Lamb, M., Sharp, S. J., Simmons, R. K., & Griffin, S. J. (2017). Bidirectional association between physical activity and muscular strength in older adults: Results from the UK Biobank study. *International Journal of Epidemiology*, 46(1), 141-148. doi: 10.1093/ije/dyw054

Durkalec-Michalski, K., Nowaczyk, P. M., Podgórski, T., Kusy, K., Osiński, W., & Jeszka, J. (2019). Relationship between body composition and the level of aerobic and anaerobic capacity in highly trained male rowers. *Journal of Sports Medicine and Physical Fitness*, 59(9), 1526-1535. doi: 10.23736/s0022-4707.19.08951-5

Girard, O., & Millet, G. P. (2009). Physical determinants of tennis performance in competitive teenage players. *The Journal of Strength and Conditioning Research*, 23(6), 1867-1872. doi: 10.1519/JSC.0b013e3181b3df89

Giuliano, C., Karahalios, A., Neil, C., Allen, J., & Levinger, I. (2017). The effects of resistance training on muscle strength, quality of life and aerobic capacity in patients with chronic heart failure - A meta-analysis. *Internationa Journal of Cardiology*, 227, 413–423. doi: 10.1016/j.ijcard.2016.11.023

Browner, W.S., Newman, T.B., & Hulley, S.B. (2007). *Estimating sample size and power: applications and examples.* In S. B. Hulley, S. R. Cummings, W. S. Browner, D. G. Grady, & T. B. Newman (Eds.), *Designing Clinical Research* (pp. 55-83). Lippincott Williams & Wilkins

Ingrová, P., Králík, M., & Bártová, V. (2017). Relationships between the hand grip strength and body composition in Czech and Slovak students. *Slovenská Antropológia*, 20(1), 30-43. doi: 10.4236/health.2012.41001

Kim, Y., White, T., Wijndaele, K., Westgate, K., Sharp, J. S., Helge, W. J,… Brage, S. (2018). The combination of cardiorespiratory fitness and muscle strength, and mortality risk. *European Journal of Epidemiology,* 33(10), 953-964. doi: 10.1007/s10654-018-0384-x

Kuh, D., Bassey, E. J., Butterworth, S., Hardy, R., & Wadsworth, M. E. (2005). Grip strength, postural control, and functional leg power in a representative cohort of British men and women: associations with physical activity, health status, and socioeconomic conditions. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences,* 60(2), 224-231. doi: 10.1093/gerona/60.2.224

Matsudo, V. K. R., Matsudo, S. M., Rezende, L. F., & Raso, V. (2015). Handgrip strength as a predictor of physical fitness in children and adolescents. *Revista Brasileira de Cineantropometria e Desempenho Humano*, 17(1), 1–10. doi: 10.5007/1980-0037.2015v17n1p1

McRae, G., Payne, A., Zelt, J. G. E., Scribbans, T. D., Jung, M. E., Little, J. P.,… Gurd B. J. (2012). Extremely low volume, whole-body aerobic – resistance training improves aerobic fitness and muscular endurance in females. *Applied Physiology, Nutrition and Metabolism,* 37(6), 1124-1131. doi: 10.1139/h2012-093

Mitropoulos, A., Gumber, A., Crank, H., & Klonizakis, M. (2017). Validation of an arm crank ergometer test for use in sedentary adults. *Journal of Sports Science and Medicine,* 16(4), 558-564.

Moberg, L. L., Lunde, L. K., Koch, M., Tveter, A. T., & Veiersted, K. B. (2017). Association between VO-2max, handgrip strength, and musculoskeletal pain among construction and health care workers. *BMC Public Health,* 17(1), 272. doi: 10.1186/s12889-017-4173-3

Muollo, V., Rossi, A., Milanese, C., Masciocchi, E., Taylor, M., Zamboni, M.,… Pellegrini B. (2019). The effects of exercise and diet program in overweight people – Nordic walking versus walking. *Clinical Interventions in Aging*, 14, 1555–1565. doi: 10.2147/CIA.S217570

Nazerian, R., Shakeri, E., Sadegh, N., Ibrahim, M. D., Roudini, M., & Korhan, O. (2016). A new method to evaluate effect of body mass index and gender factors on maximal aerobic power. *Journal of Scientific Research and Reports,* 9(3), 1–11. doi: 10.9734/JSRR/2016/19882

Peterson, S. J., Park, J., Zellner, H. K., Moss, O. A., Welch, A., Sclamberg, J., … Foley, S. (2019). Relationship between Respiratory Muscle Strength, Handgrip Strength, and Muscle Mass in Hospitalized Patients. *Journal of Parenteral and Enteral Nutrition,* 44(5), 831-836. doi: 10.1002/jpen.1724

Pizzigalli, L., Cremasco, M., La Torre, A., Rainoldi, A., & Benis, A. (2016). Hand grip strength and anthropometric characteristics in Italian female national basketball teams. *Journal of Sports Medicine and Physical Fitness,* 57(5), 521–528. doi: 10.23736/S0022-4707.16.06272-1

Scribbans, T. D., Vecsey, S., Hankinson, P. B., Foster, W. S., & Gurd, B. J. (2016). The effect of training intensity on VO-2max in young healthy adults: a meta-regression and meta-analysis. *International Journal of Exercise Science*, 9(2), 230-247.

Sutter, T., Toumi, H., Valery, A., El Hage, R., Pinti, A., & Lespessailles, E. (2019). Relationships between muscle mass, strength and regional bone mineral density in young men. Plos One, 14(3), e0213681. doi: 10.1371/journal.pone.0213681

Thomaes, T., Thomis, M., Onkelinx, S., Goetschalckx, K., Fagard, R., Cornelissen, V.,…Vanhees L. (2012). Muscular strength and diameter as determinants of aerobic power and aerobic power response in CAD patients. *Acta Cardiologica,* 67(4), 399–406. doi: 10.1080/AC.67.4.2170680

Thomas, S., Reading, J., & Shephard, R. J. (1992). Revision of the physical activity readiness questionnaire (PAR-Q). *Canadian Journal of Sport Sciences,* 17(4), 338-345.

Wallymahmed, M. E., Morgan, C., Gill, G. V., & MacFarlane, I. A. (2007). Aerobic fitness and hand grip strength in type 1 diabetes: relationship to glycaemic control and body composition. *Diabetic Medicine*, 24(11), 1296–1299. doi: 10.1111/j.1464-5491.2007.02257.x

Williams, M. A., Haskell, W. L., Ades, P. A., Amsterdam, E. A., Bittner, V., Franklin, B. A., ….. Stewart, K. J. (2007). Resistance exercise in individuals with and without cardiovascular disease: 2007 update: A scientific statement from the American Heart Association Council on Clinical Cardiology and Council on Nutrition, Physical Activity, and Metabolism. *Circulation*, 116(5), 572–584. doi: 10.1161/CIRCULATIONAHA.107.185214

Wilson, T. M., & Tanaka, H. (2000). Meta-analysis of the age-associated decline in maximal aerobic capacity in men: relation to training status. *American Journal of Physiology: Heart and Circulatory Physiology,* 278(3), 829–834. doi: 10.1152/ajpheart.2000.278.3.H829

Wind, A. E., Takken, T., Helders, P. J. M., & Engelbert, R. H. H. (2010). Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? *European journal of Pediatrics,* 169(3), 281–287. doi: 10.1007/s00431-009-1010-4

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ORIGINAL SCIENTIFIC PAPER

The Physical Activity Enjoyment Scale (Paces) as a Two-Dimensional Scale: Exploratory and Invariance Analysis

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Abstract

The current study aims to examine the Physical Activity Enjoyment Scale (PACES) as a two-dimensional scale assessing two correlated but distinct dimensions of enjoyment. In total, 277 individuals (female = 108) aged between 18 and 53 years (M = 35.66; SD = 7.42) participated in the study. The unidimensional model solution displayed good fit. However, the exploratory structural equation modelling specification considering two correlated but distinct dimensions of enjoyment showed a better fit. This study was the first attempt to examine the possible existence of two dimensions within the eight-item PACES measure. The distinct aspect of the current research is to emphasize the complex and constant process of instrument validation. Scales should be viewed as a continuous process, and future methodological procedures will increase our understanding of instrument examination with more innovative statistical approaches.

Keywords: *enjoyment, exploratory analysis satisfaction, fun*

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Introduction

People are emotional beings who relate to behaviours that are interesting and promote pleasure. In contrast, individuals avoid engaging in activities they do not like or have an associated negative meaning. Hence, it is expected that behaviours (e.g., physical activity) individuals like and are pleasurable will be pursued with greater engagement and commitment than activities they do not like (Jekauc & Brand, 2017).

One theoretical outcome of self-determined motivation and predictor of intentions towards physical activity itself is enjoyment (Mullen et al., 2011). The experience of enjoyment reflects generalized feelings, such as pleasure, liking, and satisfaction (Moore Yin, et al., 2009) and has recently received great attention towards its significant association with several outcomes in different contexts, such as physical education (Gardner, et al., 2017), sport (Teixeira, et al., 2019), and exercise (Rodrigues, et al., 2020).

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Even though enjoyment has been assessed in several studies in recent years (Monteiro, et al., 2018; Mullen et al., 2011; Rodrigues, et al., 2019), no measures of a multi-dimensional structure have been considered for practical use. Instead, researchers have assumed enjoyment to be a global experience of liking and fun, a possible bias issue associated with the fact that there could be different dimensions of enjoyment individuals experience when exercising. As stated by several authors (Gråstén, et al., 2012; Gråstén & Watt, 2017; Moreno, et al.; López, 2014), enjoyment could be defined as a multi-dimensional structure related to enthusiasm, excitement, and/or cognition. Therefore, this research intends to review the assessment of enjoyment when engaging in physical activity.

The enjoyment of physical activity is defined as a positive outcome to the movement experience that reflects feelings such as enthusiasm and excitement resulting from the activity itself (Raedeke, 2007). Thus, individuals who engage in exercise and sports for intrinsic motivations are more likely to experience higher levels of enjoyment (Monteiro et al., 2018; Rodrigues et al., 2020). Extending its importance, enjoyment can also be a predictor of behavioural outcomes, such as intentions towards leisure-time physical activity (Gardner, et al., 2017), commitment to sport (Granero-Gallegos, et al., 2017), and persistence in exercise (Rodrigues et al., 2018).

To date, several instruments have been developed and applied to measure enjoyment in physical activity. For example, Markland and Hardy (1993) have created the Exercise Motives Scale (EMI), encompassing four items measuring the experience of joy when exercising; Kendzierski and DeCarlo (1991) validated their Physical Activity Enjoyment Scale (PACES), which is an 18-item scale focused on assessing enjoyment only. In some studies, enjoyment has been assessed using single items (DiLorenzo, et al, 1998), representing little evidence of validity and reliability. Nevertheless, the most commonly used instrument nowadays is the eight-item version of PACES (Mullen et al., 2011), which advanced clinical assessment and reduced participants' burden. This shorter version has been translated and validated in several countries, including Portugal (Monteiro, et al., 2017; Teques, et al., 2017), Spain (Moreno et al., 2014), Germany (Jekauc, et al., 2013), and China (Chung & Leung, 2018).

Little is known about the existence of different dimensions of enjoyment during physical activity. Looking at the PACES measure, the items could hold different types of enjoyment. For example, the item "It is very stimulating" could represent a more emotional representation or satisfaction on engaging in physical activity, whereas the item "It is a lot of fun" seems more relatable to fun and high arousal during training sessions. Kendzierski and DeCarlo (1991) have called for further analysis regarding PACES, suggesting that this scale could be broken down into components. Crooker, Marcel, and Gessaroli (1995) reinforced this statement, suggesting that the factor structure might not be unidimensional; rather, items seem to reflect different types of enjoyment. More recently, other authors (Gråstén & Watt, 2017; Jekauc et al., 2013; Moreno et al., 2014) have suggested that enjoyment could have different sides, leading to different outcomes; therefore, researchers have called for more studies on physical activity enjoyment assessment.

Due to the widespread use of PACES, there is a need to rigorously evaluate the properties of the scale to determine a possible two-correlated factor structure that can be uniformly applied to future settings. Furthermore, a key concern currently limiting the expansion of the field of the assessment of physical activity enjoyment is the lack of exploratory measurement models for quantifying whether enjoyment is a global experience of liking something, or is it a multi-dimensional construct that could be associated with different outcomes (e.g., intention, engagement). This study explored PACES as a multi-dimensional measure of enjoyment. It is hypothesized that PACES could have a two-dimensional factor structure, assessing correlated but distinct constructs according to previous assumptions (Kendzierski & DeCarlo, 1991). To confirm if the hypothesized two-correlated model would be equivalent between groups with different characteristics, measurement invariance analysis is performed between male and female. Based on previous assumptions, it is expected that the model would be equivalent between genders (Monteiro et al., 2017).

Methods

Participants and procedures

In total, 277 individuals (female = 108) aged between 18 and 53 years (M = 35.66; SD = 7.42) participated in current study. This study was approved by the Ethical Committee (registration number: CE-UBI-pJ-2018-044:ID683); all procedures conducted in this research were in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Then, sport club managers and gym executives were contacted, and objectives were explained. After obtaining approval, individuals were approached before training sessions and asked to participate voluntarily in this study. Participants who agreed signed informed consent prior to completing the questionnaire. Individuals took approximately 10 minutes to complete the scale.

Measure

Individuals completed the eight-item PACES version (Mullen et al., 2011). This scale comprises eight items measuring the degree of enjoyment individuals feel when exercising, to which participants respond to each item using a seven-point Likert scale anchored from 1 ("totally disagree") to 7 ("totally agree").

Statistical analysis

All procedures were performed using the Mplus 7.4 software (Muthén & Muthén, 2010). We used the Robust Maximum Likelihood estimator since it is robust to the non-normality and non-independence of observations (Yuan & Bentler, 2002). According to the theoretical hypothesis, we tested a unidimensional and a two-dimensional model specification. The unidimensional specification model was conducted to test if individuals perceive items as one factor only. A two-dimensional model was performed that considered the analysis of four specialists, each from different fields of scientific expertise (teacher, clinical psychologist, sport psychologist, and researcher in sport science). Next, a second evaluation panel composed of four other specialists evaluated the item distribution

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into two factors; together with the first panel of specialists, they came to a consensual judgment of the item distribution. In the unidimensional model, items were restricted to load only on their respective factor; whereas in Exploratory Structural Equation Modelling (ESEM) cross-loadings were targeted to be as close to zero as possible using the oblique target rotation procedure (Browne, 2001).

Chi-square statistics will be reported for visual orientation, but will not be considered to assess model fit since they are oversensitive on sample size and model complexity (Hair, et al., 2019). Therefore, this research considered traditional and incremental goodness-of-fit indexes: Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Root Mean Square Error of Approximation (RMSEA). As cutoffs, values ≥0.90 for CFI and TLI are typically interpreted to reflect acceptable fit (Byrne, 2016; Hair, et al., 2014; Marsh, et al., 2004). For RMSEA, values of ≤0.80 were suggestive of reasonable fit (Marsh et al., 2004). Raykov's composite reliability coefficient (1997) was calculated for the subscale scores. Coefficient scores above or equal 0.70 provide acceptable internal consistency (Raykov, 1997).

To confirm if the hypothesized two-correlated model would be equivalent between groups with different characteristics, measurement invariance analysis was performed between males and females. First, the two-correlated model was tested in each sample. Then, for multigroup analysis, several levels of measurement invariance were measured according to Hair et al. (2019): configural invariance, weak factorial invariance, strong invariance, and strict factorial invariance. Model comparisons were made according to differences in CFI and TLI (Marsh et al., 2010). Differences below 0.01 were indicative of invariance moving ahead to the next level. Measurement invariance was achieved if all levels were below cutoffs, indicating that the model is equivalent between groups (Byrne, 2016).

Results

Results of the factor structure of the models are displayed in Table 1. The unidimensional model provided an acceptable fit to the data. Then, the two-correlated factor model was tested considering item distribution based on the evaluation panel described earlier. Items 1, 3, 6, and 7 were loaded into one specific factor, and items 2, 4, 5, and 8 were loaded into another factor. The two-correlated model solution displayed excellent fit, suggesting the existence of two dimensions within the shorter eight-item measure.

Table 1. Model fit indexes

Model	χ^2	df	CFI	TLI	RMSEA
Unidimensional factor CFA	248.829	20	.949	.943	.076
Two-correlated factor ESEM	120.865	13	.981	.959	.065
Two-correlated factor ESEM - female	118.369	13	.997	.996	.040
Two-correlated factor ESEM - male	117.478	13	.997	.987	.042

Note. χ^2 = chi-square test; df = degrees of freedom; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; RMSEA = Root Mean Squared Error of Approximation..

In the analysis of factor loadings (see Table 2), all items significantly loaded their respective factors in both unidimensional and two-correlated factor models. Several cross-loadings were found in the two-correlated factor specification; however, differences in the factor loading between target factor and non-target factor were below 0.15, suggesting retaining the item in the factor in which it loaded the most. Composite reliability scores were above acceptable (>.70) in the unidimensional and two-correlated model specification, as seen in Table 2. In light of these results, the two-correlated factor model was retained for further analysis.

Table 2. Factor loadings of the original and the re-specified factor models

	Unidimensional model	Two-correlated factor model	
	λ	F1λ	F2λ
Item 1	.80**	.86**	.18
Item 2	.81**	.31*	.75**
Item 3	.83**	.80*	.40*
Item 4	.89**	49**	.83**
Item 5	.87**	.22*	.79**
Item 6	.89**	.79**	.25*
Item 7	.84**	.82**	.39*
Item 8	.80**	.10**	.74**
CR	.95	.89	.88

Note. λ = factor loadings; F = Factor; target loadings are in bold; CR = Composite Reliability; * p <0.05; ** p <0.001.

The two-correlated model was used to test measurement invariance between genders. The two-correlated model displayed acceptable fit in all samples, as seen in Table 3. Multigroup analysis shows that the measurement model was equivalent between samples and between gender since all invariance criteria were met (ΔCFI<.01) and (ΔTLI<.01).

Table 3. Multigroup analysis of the two-correlated factor model between genders

Model	χ^2	df	CFI	ΔCFI	TLI	ΔTLI
Configural Invariance	206.559	52	.998	-	.997	-
Weak Factorial Invariance	198.449	50	.998	.001	.998	.001
Strong Invariance	139.184	54	.999	.001	.999	.002
Strict Factorial Invariance	128.177	48	.999	.001	.999	.002

Note. ΔCFI = differences in CFI; ΔTLI = differences in TLI.

Discussion

The aim of this research consisted of exploring the PACES as a two-dimensional scale assessing two correlated but distinct factors of enjoyment. The results reveal that the PACES could have two representations of enjoyment in individuals engaging in physical activity. Also, male and female physical activity participants experience both types of proposed enjoyment dimensions equally. The results will be discussed based on existing literature.

The first step consisted in examining a model considering the eight-item PACES as a one-factor measure. The CFA specification had an adequate fit, supporting previous studies using the same scale in the physical activity domains (Monteiro et al., 2017; Teques et al., 2017) and other health and academic contexts (Chung & Leung, 2018; Moreno et al., 2014; Mullen et al., 2011). Thus, we moved forward on testing a possible two-dimensional factor model. Following examination of the hypothesis and evaluations made by the panel of specialists, items were loaded into two specific factors, and unintended items were forced to zero following assumptions of ESEM analysis. Items 1 (I find it pleasurable), 3 (It is very pleasant), 6 (It is very exhilarating), and 7 (It is very stimulating) were loaded on Factor 1. Items 2 (It is very refreshing), 4 (It is very invigorating), 5 (It is very gratifying), and 8 (It is a lot of fun) were loaded on Factor 2. The two-correlated model specification provided greater fit to the data (Hair et al., 2019) compared to the unidimensional model solution, showing possible existence of two dimensions of enjoyment.

Items loaded their respective factor significantly, showing no significant cross-loadings on unintended factors. These results support previous assumptions of a multi-dimensional PACES scale (Crooker et al., 1995; Kendzierski & DeCarlo, 1991; Moreno et al., 2014), showing that the eight-item version could be suited in a two-correlated factor model. In this regard, to confirm if the hypothesized two-correlated model would be equivalent between groups with different characteristics, measurement invariance analysis was performed between males and females.

With respect to the measurement invariance analysis, the results support the equivalence of the two-correlated model version between gender since invariance levels were respected, as suggested by several authors (Byrne, 2017; Marsh et al., 2010). The invariance between groups indicates that the two-correlated factor model is being measured across groups, being interpreted in a conceptually similar manner by individuals representing different groups. Current findings showed that the two-correlated factor model is a reliable and valid measure on assessing two distinct factors of physical activity enjoyment in female and male individuals engaging in either sports or exercise. However, contrary to the results of Moore et al. (2009), in the present research, the instrument was invariant between genders. Differences could rely on the nature of physical activity and age. In this study, participants were physically active adults, whereas in the study conducted by Moore et al. (2009) the sample was composed of children in the physical education context. Nevertheless, the measurement model was equivalent between gender, showing its applicability in both male and female physical activity participants as displayed in previous research (Monteiro et al., 2017; Moore et al., 2009; Teques et al., 2017).

At a theoretical standpoint and considering the reports from the panel of specialists, defining the two dimensions of the PACES as "fun" and "satisfaction" is suggested. Fun (item 2, 4, 5, and 8) could be defined as a pleasurable or amusement entertainment. In fact, Item 2 "I find it a lot of fun" reflects the particularity of recreational behaviour very well, being encountered in the physical activity domain. Thus, fun could be more pronounced when others are involved. That is, engaging in physical activity with peers, friends, and other important persons could increase the likelihood of experiencing fun (Monteiro et al., 2017). Also, when people engage in behaviour for fun, they seek the experience of pleasure and delight. The experience of having fun could thus be related to a state of flow (Csikszentmihalyi, 2013). When an individual is in the flow state, they are completely connected with the behaviour at hand, and without any conscious decision making, they lose awareness of time. As typically stated, "time flies when you are having fun".

Satisfaction (item 1, 3, 6 and 7) is at the core of the in-moment experience, reflecting the individual liking of physical activity, which results from personal interest towards the behaviour. Specifically, it is argued that satisfaction during physical activity is a satisfying feeling about the behaviour and willingness to continue pursuing it on the long-term (Rodrigues et al., 2019). Enjoyment should, therefore, be provided in every training session. Thus, arguably, enjoyment satisfaction would be a stronger predictor pf physical activity persistence, compared to fun. However, more studies are needed to explore this hypothesis based on current findings and previous studies in the sport (Teixeira et al., 2019) and exercise context (Rodrigues et al., 2020).

It is noteworthy that these are suggestions for defining these proposed factors, and more studies are warranted. Even though the measurement model displayed an existing two-factor structure, we encourage more studies to examine if the model would display similar results as those here reported. We intend to motivate a discussion and research about the possibility of the distinctiveness of enjoyment dimensions and the similarities of these types of enjoyment and their possible interrelationships. Moreover, future research will lead to new and powerful insights, albeit inevitably demonstrating contradictory results, which should be viewed as research enhancement rather than failure.

Some limitations should be addressed. We analysed the eight-item version and not the original eighteen-item proposed by Kendzierski and DeCarlo (1991). The original ver-

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sion could represent more dimensions of enjoyment during physical activity. Crooker et al. (1995) suggested that the factor structure might not be unidimensional; rather, items seem to identify the antecedents and consequences of enjoyment. In this regard, more research is needed on the assessment of physical activity enjoyment. Finally, longitudinal measurement seems paramount, since enjoyment may fluctuate over time (Chung & Leung, 2018).

Conclusion

The current study filled a gap to allow future research to examine a possible multi-dimensional measure of the PACES (Kendzierski & DeCarlo, 1991). The two-correlated version presented reliable and validated results in the physical activity context. This instrument seems to measure two dimensions of enjoyment when engaging in training sessions. Assessing enjoyment increases health, exercise, and sport professionals' insight into how to promote physical activity. Since it presents an outcome of intrinsic motivation, as well as a predictor of several cognitive and behavioural outcomes, enjoyment should be constantly measured as a way to understand how individuals are experiencing satisfaction and fun during physical activity. The distinctiveness of current research is to emphasize the complex and constant process of instrument validation to advance theoretical assumptions. Scales should be viewed as a continuous process, and future methodological procedures will increase our understanding of instrument examination with more innovative statistical approaches..

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References

Browne, M. (2001). An overview of analytic rotation in exploratory factor analysis, *Multivariate Behavioral Research*, 36 (1), 111–150.

Byrne, B. (2016). *Structural equation modeling with AMOS. Basic concepts, applications, and programming* (3rd ed.): New York: Taylor & Francis Group, LLC.

Chung, P. K., & Leung, K. M. (2018). Psychometric Properties of Eight-Item Physical Activity Enjoyment Scale in a Chinese Population. *Journal of Aging & Physical Activity*, 1-6. doi: 10.1123/japa.2017-0212

Crooker, P., Marcel, B., & Gessaroli, M. (1995). Measuring enjoyment in youth sport settings: A confirmatory factor analysis of the Physical Activity Enjoyment Scale. *Journal of Sport & Exercise Psychology*, 17(2), 200-205. doi: 10.1123/jsep.17.2.200

DiLorenzo, T., Stucky-Ropp, R., Vander Wal, J., & Gotham, H. (1998). Determinants of exercise among children. II. A longitudinal analysis. *Preventive Medicine*, 27(3), 470-477. doi: 10.1006/pmed.1998.0307

Gardner, L., Magee, C., & Vella, S. (2017). Enjoyment and Behavioral Intention Predict Organized Youth Sport Participation and Dropout. *Journal of Physical Activity & Health*, 14(11), 861-865. doi: 10.1123/jpah.2016-0572

Granero-Gallegos, A., Gomez-Lopez, M., Rodriguez-Suarez, N., Abraldes, J., Alesi, M., & Bianco, A. (2017). Importance of the Motivational Climate in Goal, Enjoyment, and the Causes of Success in Handball Players. *Frontiers in Psychology*, 8, 2081. doi: 10.3389/fpsyg.2017.02081

Gråstén, A., & Watt, A. (2017). A motivational model of physical education and links to enjoyment, knowledge, performance, total physical activity and body mas index. *Journal of Sport Science & Medicine*, 16(318-327).

Gråstén, A., Jaakola, T., Liukkonen, J., Watt, A., & Yli-Piipari, S. (2012). Prediction of Enjoyment in School Physical Education. *Journal of Sport Science and Medicine*, 11(2), 260-269.

Hair, J., Black, W., Babin, B., & Anderson, R. (2019). *Multivariate Data Analysis* (8th ed.): New Jersey: Pearson Educational, Inc.

Jekauc, D., & Brand, R. (2017). Editorial: How do Emotions and Feelings Regulate Physical Activity? *Frontiers in Psychology*, 8, 1145. doi: 10.3389/fpsyg.2017.01145

Jekauc, D., Voelkle, M., Wagner, M. O., Mewes, N., & Woll, A. (2013). Reliability, validity, and measurement invariance of the German version of the physical activity enjoyment scale. *Journal of Pediatric Psychology*, 38(1), 104-115. doi: 10.1093/jpepsy/jss088

Kendzierski, D., & DeCarlo, K. (1991). Physical Activity Enjoyment Scale: Two Validation Studies. *Journal of Sport & Exercise Psychology*, 13(1), 50-64. doi: 10.1123/jsep.13.1.50

Markland, D., & Hardy, L. (1993). The Exercise Motivations Inventory: preliminary development and validity of a measure of individuals' reasons for participation in regular physical exercise. *Personality & Individual Differences*, 15(3), 286-296. doi: 10.1016/0191-8869(93)90219-S

Marsh, H., Hau, K., & Wen, Z. (2004). In search of Golden Rules: comment on hypothesis-testing approaches to setting cutoff values for fit indexes and dangers in overgeneralizing Hu and Bentler's (1999) Findings. *Structural Equation Modeling: A Multidisciplinary Journal*, 11(3), 320-341. doi: 10.1207/s15328007sem1103_2

Monteiro, D., Nunes, G., Marinho, D., Couto, N., Antunes, R., Moutão, J., & Cid, L. (2017). Translation and adaptation of the physical activity enjoyment scale (PACES) in a sample of Portuguese athletes, invariance across genders nature sports and swimming. *Brazilian Journal of Kinanthropometry & Human Performance*, 19(6), 631-643. doi: 10.5007/1980-0037.2017v19n6p631

Monteiro, D., Pelletier, L., Moutão, J., & Cid, L. (2018). Examining the motivational determinants of enjoyment and the intention to continue of persistent competitive swimmers. *International Journal of Sport Psychology*, 49(6), 484.504. doi: 10.7352/IJSP.2018.49.484

Moore, J., Yin, Z., Hanes, J., Duda, J., Gutin, B., & Barbeau, P. (2009). Measuring Enjoyment of Physical Activity in Children: Validation of the Physical Activity Enjoyment Scale. *Journal of Applied Sport Psychology*, 21(S1), S116-S129. doi: 10.1080/10413200802593612

Moreno, J.-A., González-Cutre, D., Martínez, C., Alonso, N., & López, M. (2014). Propiedades psicométricas de la Physical Activity Enjoyment Scale (PACES) en el contexto español. *Estudios de Psicología*, 29(2), 173-180. doi: 10.1174/021093908784485093

Mullen, S., Olson, E., Phillips, S., DSzabo, A., Wójcicki, T., Mailey, E., . . . McAuley, E. (2011). Measuring enjoyment of physical activity in older adults: invariance of the physical activity enjoyment scale (paces) across groups and time.

International Journal of Behavioral Nutrition & Physical Activity, 8, 103. doi: 10.1186/1479-5868-8-103
Muthén, L., & Muthén, B. (2010). *Mplus User's Guide.* Muthén & Muthén: Los Angeles.
Raedeke, T. D. (2007). The Relationship Between Enjoyment and Affective Responses to Exercise. *Journal of Applied Sport Psychology*, 19(1), 105-115. doi: 10.1080/10413200601113638
Raykov, T. (1997). Estimation of Composite Reliability for congeneric measures. *Applied Psychological Measurement*, 21(2), 173-184. doi: 10.1177/01466216970212006
Rodrigues, F., Bento, T., Cid, L., Pereira Neiva, H., Teixeira, D., Moutao, J., Marinho, D., Monteiro, D. (2018). Can Interpersonal Behavior Influence the Persistence and Adherence to Physical Exercise Practice in Adults? A Systematic Review. *Frontiers in Psychology*, 9, 2141. doi: 10.3389/fpsyg.2018.02141
Rodrigues, F., Teixeira, D. S., Neiva, H., Cid, L., & Monteiro, D. (2020). The bright and dark sides of motivation as predictors of enjoyment, intention, and exercise persistence. *Scandinavian Journal of Medicine & Science in Sports*, 30(4), 787–800. https://doi.org/10.1111/sms.13617
Rodrigues, F., Teixeira, D., Cid, L., & Monteiro, D. (2019). Have you been exercising lately? Testing the role of past behavior on exercise adherence. *Journal of Health Psychology*, 1359105319878243. doi: 10.1177/1359105319878243
Teixeira, D. S., Pelletier, L. G., Monteiro, D., Rodrigues, F., Moutao, J., Marinho, D., & Cid, L. (2019). Motivational patterns in persistent swimmers: A serial mediation analysis. *European Journal of Sports Science*. doi: 10.1080/17461391.2019.1675768
Teques, P., Calmeiro, L., Silva, C., & Borrego, C. (2017). Validation and adaptation of the Physical Activity Enjoyment Scale (PACES) in fitness group exercisers. *Journal of Sport & Health Science*. doi: 10.1016/j.jshs.2017.09.010
Yuan, K., & Bentler, P. (2002). Structural Equation Modeling with Robust Covariances. *Sociological Methodology,* 28(1). doi: 10.1111/0081-1750.00052

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ORIGINAL SCIENTIFIC PAPER

Validation in Young Soccer Players of the Modified Version of the Harre Circuit Test: The Petrucci Ability Test

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Abstract

The evaluation of soccer players' physical fitness from youth onward is important for monitoring performance and planning training. While health-related factors present valid and reliable tests, the skill-related component should be studied in depth. An interesting test to evaluate the skill-related factors is the Harre circuit test (HTC); unfortunately, this test includes the somersault, an element not present in soccer. The aim of the present study is the validation of the Petrucci ability test (PAT), a variation of the HTC without the somersault for young soccer players. Children and adolescents (age range 10–13 years old) soccer players concluded the 20-m, the HTC and the PAT. To establish the validity of the PAT, correlation analysis has been performed, which presented a $p < 0.0001$ between PAT and HTC; $p < 0.001$ between PAT and a 20-m test; and $p < 0.0001$ between HTC and the 20-m test. The results suggest that the PAT can be a valid substitute for the evaluation of the skills-related components of young soccer players and, consequently, also of athletes and schoolchildren.

Keywords: *skill-related evaluation, youth, physical fitness, football, protocol*

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Introduction

Soccer, or association football, is a widely practised activity in the world and performance is influenced by physical, biomechanical, technical, mental and tactical factors (Stolen, et al., 2005). It is important to monitor athletic performance and plan training (Svensson & Drust, 2005), and the aspects to be evaluated are sprints, jumps, turns, shots, and tackles (Hoff & Helgerud, 2004). Also, in children and adolescents, an appropriate evaluation to identify talents or to find the suitable role on the soccer team is necessary (Hammami et al., 2013; Lago-Penas, et al., 2014).

The evaluation of the soccer player's physical fitness (PF) performance can be accurately and objectively performed through laboratory and field tests (Hoff, 2005; Svensson & Drust, 2005; Tabacchi, 2019). While laboratory tests are usually more reliable, field tests, instead, are generally easier to administer, as well as being less costly and time-consuming (Heyward, 1991; O'Reilly & Wong, 2012; Svensson

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& Drust, 2005). Furthermore, field tests are more ecologically valid and suitable in population-based studies, such as in a school or college setting (Artero et al., 2011). Finally, field-based tests are more sport-specific and sensitive to seasonal changes (O'Reilly & Wong, 2012). Given that PF is composed of health-related (cardiorespiratory endurance, muscular strength, body composition and flexibility), and skill-related components (agility, balance, coordination, power, reaction time and speed) (Caspersen, et al., 1985), it is necessary to test these characteristics properly among soccer players.

Health-related PF components are tested by valid and reliable field-test protocols, such as the Cooper test (Cooper, 1968) for cardiorespiratory endurance, the 20 m Shuttle Run Test (Leger & Lambert, 1982) or the intermittent Yo-Yo test (Paul & Nassis, 2015) for muscular endurance, vertical jumps (Petrigna et al., 2019) for muscular power, and the sit-and-reach test (Wells, 1952) for flexibility. Also, some skill-related components are evaluated with valid and reliable tests, such as speed, assessed with sprints from 5 to 60 metres (Hoff, 2005; Paul & Nassis, 2015), agility and balance, evaluated with the T-test and the Flamingo balance test respectively (Pojskic et al., 2018; Tabacchi, 2019; Walaszek, et al., 2017). The reaction time can be tested through the athlete's responses to determined inputs, such as sounds or lights (Tabacchi, 2019) while for the evaluation of coordinative abilities the Körperkoordinationstest für Kinder (KTK) test could be adopted (Tabacchi, 2019), a valid test for gross motor coordination in school-aged children (Iivonen, et al., 2015; Iivonen & Laukkanen, 2014; Vandorpe et al., 2011). Other tests combine more skill-related components, such as the performance of sprints with changes of direction (speed and agility) (Iivonen & Laukkanen, 2015; Iivonen & Laukkanen, 2014; Vandorpe et al., 2011). The Harre circuit test (HTC) (Harre, 1982) evaluates dynamic motor coordination, coordinative abilities, and cognitive capabilities (reaction time and space perception) (Harre, 1982; Trecroci, et al., 2015; Zatsiorsky, 2006), also in children (Chiodera et al., 2008; Dallolio, et al., 2016). Due to the inclusion of different skill-related components with the HTC, which could limit the use of this test in those sports for which the somersault is not required (i.e., football, basketball, water polo), the objective of the present study is to evaluate if the HTC in a modified version (without the somersault), called the Petrucci ability test (PAT), is valid for young soccer players.

Methods

A total of sixty-nine children and adolescents (11.1 ± 1 years; 41.2 ± 7.7 kg; 148.3 ± 9.6 cm) of the U.S. Città di Palermo soccer school (Palermo, Italy) have been recruited for the study.

Height and weight were measured by trained investigators following a standardized protocol. Height was measured to the nearest 0.1 cm with a stadiometer (SECA, Hamburg, Germany) with feet together. Weight was also evaluated to the nearest 0.1 cm with a balance SECA (Hamburg, Germany). Body mass index (BMI) (kg/m^2) and Body surface area (m^2) were calculated.

Children and adolescents' parents were informed about the purpose of the study and the risks of the research project. Furthermore, informed consent forms were provided by parents or legal guardians.

The study has been approved by the local Bioethics Committee of the Università degli Studi di Palermo and was in accordance with the Helsinki Declarations revised in 2013.

Study design

The testing session took one day, and the tests were proposed at the beginning of the sports season. During the session, participants were screened against the eligibility criteria, following which the 20-m, the HTC and the modified version of the Harre circuit test, named PAT, were proposed.

The test was performed after a generalized warm-up that consisted of 6 minutes of a low-intensity run (about 7 km/h), two series of high running skips for eight metres, and two series of back running kicks with a recovery time of thirty seconds between series. The three tests were proposed in random order with a recovery time between tests of five minutes.

The 20-metre test required participants to run 20 metres at their maximum speed. The time was measured using a Garmin stopwatch (USA). Participants started the test from a pre-established standing position; after the start signal, they had to run 20 metres. The time was measured in seconds.

The Harre circuit test followed the procedure was followed (Harre, 1982). After the start from an upright position, the participants perform a somersault on a mattress, followed by three passages above and below of three obstacles (50 cm high). Before the obstacles, participants have to move to their right and touch an indicative ball/cone. The test was stopped when the athletes passed the finish line. The test was also stopped if an obstacle was touched or the execution was not the correct one.

The Petrucci ability test protocol was adapted previously (Alesi et al., 2014) and, differently from the HCT, the PAT consisted of running directly to the ball/cone without the somersault. Furthermore, the athletes should not touch the ball/cone when they turn around it. The second part of the test followed the same procedure as the test HTC. In this case, the time to complete the test was evaluated, and the test was also stopped if an obstacle was touched or the execution was not the correct one.

Statistical analysis

Statistical analysis was performed with the GraphPad Prism (Vers. 5.0) software. The Shapiro-Wilk test to evaluate data distribution was performed, and normality was set with alpha at 0.05. Data are presented as mean and standard deviations. The parametric Pearson test has been performed to evaluate the correlation between the PAT and: (i) the 20-m test; (ii) HTC; and (iii) age. The statistical significant has been set with $p < 0.05$.

Results

All participants completed the testing session. The results for age, PAT, HTC, and 20-m sprint test are normally distributed. The Pearson test showed an r-value of 0.51 ($p < 0.0001$) between the PAT and the 20-m test (Figure 1), while a 0.83 ($p < 0.001$) between the PAT and the HTC (Figure 2). An r-value of 0.50 ($p < 0.0001$) was between the 20-m test and the HTC (Figure 3). Mean data and standard deviation for the PAT, the HTC and the 20-m tests according to the age group are presented in Table 1.

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Table 1. Data related to the physical tests carried out on the four groups (mean ± standard deviation)

	20-m run (sec)	Harre test (sec)	Petrucci ability test (sec)
10-year-olds group	4.0 ± 0.2	16.4 ± 2.2	15.1 ± 1.8
11-year-olds group	3.7 ± 0.2	15.1 ± 1.4	14.4 ± 1.2

Note. A correlation analysis between age and: (i) PAT presented and r of -0.40 ($p < 0.001$); (ii) with the 20-m test of -0.62 ($p < 0.001$) and with HTC of -0.36 ($p < 0.01$).

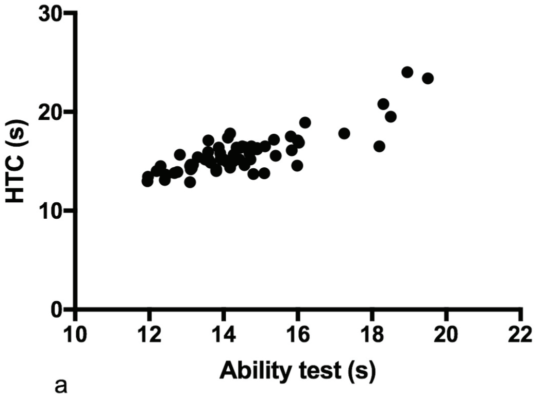

FIGURE 1. Correlation analysis between PAT and HTC (p<0.0001). All data are in seconds.

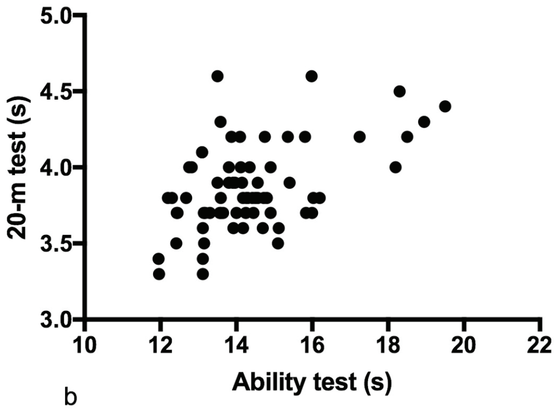

FIGURE 2. Correlation analysis between PAT and 20-m test (p<0.001). All data are in seconds.

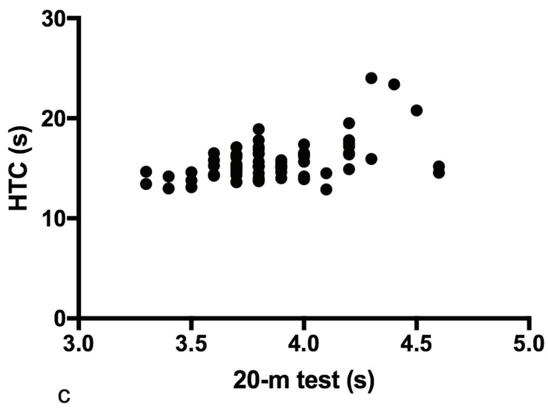

FIGURE 3. Correlation analysis between HTC and 20-m test (p<0.0001). All data are in seconds.

Discussion

The present study suggests that the PAT is equally reliable as the HCT; it is a simple, rapid and non-invasive motor skills evaluation method for young soccer players. The PAT, simplifying the HCT, allows several advantages such as the use of less equipment, the possibility of application to wider sports areas, elimination of an element (the somersault), and consequently extending the test to a wider audience.

The evaluation of lower limbs dexterity is important to guarantee to the soccer athletes the ability to perform sudden deceleration and change of direction, and this can be performed with agility tests (Lyle, et al., 2015) and the results of the present study, in which PAT and 20-m sprint test are positively correlated (r = 0.51), confirm that coordination tests are also useful.

The PAT was strongly positively associated with the HTC (r= 0.83); this is an important result for the study confirming the assumption that the two tests are interchangeable. The PAT can be used to replace the HTC; the former test measures coordination, reaction time and space perception (Harre, 1982; Trecroci et al., 2015; Zatsiorsky, 2006) with the only difference being that the ability in performance a somersault is not required. Not doing a somersault reduces the equipment needed to perform the test by making the protocol test inexpensive and feasible in a larger population, such as in schools or children to evaluate and monitor skill-related components. Evaluation and monitor of motor skill but also of PF, in general, is important because it is a marker of health status (Catley & Tomkinson, 2013), it is correlated with cardiovascular disease risk factors and skeletal health (Ortega, et al., 2008), and it presents a positive association with cognition and academic achievement (Donnelly et al., 2016). Considering the rapid rise of overweight children (Dollman, et al., 2005) with a consequent increase of cardiovascular and metabolic risk factors (Gong et al., 2013), it is vital to evaluate all PF components. Furthermore, the identification of low-level PF children should start in the schools in order to propose timely intervention (Ortega et al., 2008); consequently, other populations must be involved to confirm the feasibility of the present study.

Negative correlations exist between age and PAT (r = -0.40), meaning that the older the sample is, the faster they are; negative results were also found between age and HTC (r= -0.36) and age and 20-m sprint test (r =-0.62). These confirm the necessity of evaluating coordination constantly in youth since general and specific coordination, strongly related to speed, agility, and leg power, improve with age and during sport-specific skills acquisition (Kamandulis et al., 2013). One consideration is that, as different physical characteristics influence the test results in the T-test (agility test) (Pauole, 2000), the PAT is also influenced by multiple factors, such as lower limb strength, agility, sprint and psychological aspects, such as motivation; consequently, the interpretation of results have been made carefully.

Gender and age present differences in the PF of soccer players (Mujika, et al., 2009). Furthermore, as has been previously observed (Kaplan, et al., 2009), speed and agility performance differs between professional and amateur soccer players. Therefore, one limit of the study is the sample involved and, consequently, it is interesting to evaluate if coordination and, consequently, the time to complete the PAT is different according to the gender, age, and level of the athletes. Furthermore, a validation study is required. The strength of the present study is to present a new test to evaluate motor skills to the scientific world, as well as to teachers and coaches.

Conclusion

The PAT, simplifying the HCT, enables evaluating skill-related components in different age and physical activity level groups. The necessity of a few inexpensive pieces of equipment and the reduction of the injury risk due to the elimination of the somersault makes the PAT ideal for evaluating motor skills.

References

Alesi, M., Bianco, A., Padulo, J., Vella, F. P., Petrucci, M., Paoli, A., . . . Pepi, A. (2014). Motor and cognitive development: the role of karate. *Muscles Ligaments Tendons Journal*, 4(2), 114-120.

Artero, E. G., Espana-Romero, V., Castro-Pinero, J., Ortega, F. B., Suni, J., Castillo-Garzon, M. J., & Ruiz, J. R. (2011). Reliability of field-based fitness tests in youth. *International Journal of Sports Medicine*, 32(3), 159-169. doi: 10.1055/s-0030-1268488

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Reports*, 100(2), 126-131.

Catley, M. J., & Tomkinson, G. R. (2013). Normative health-related fitness values for children: analysis of 85347 test results on 9-17-year-old Australians since 1985. *British Journal of Sports Medicine*, 47(2), 98-108. doi: 10.1136/bjsports-2011-090218

Chiodera, P., Volta, E., Gobbi, G., Milioli, M. A., Mirandola, P., Bonetti, A., . . . Vitale, M. (2008). Specifically designed physical exercise programs improve children's motor abilities. *Scandinavian Journal of Medicine & Science in Sports*, 18(2), 179-187. doi: 10.1111/j.1600-0838.2007.00682.x

Cooper, K. H. (1968). A means of assessing maximal oxygen intake. Correlation between field and treadmill testing. *JAMA*, 203(3), 201-204.

Dallolio, L., Ceciliani, A., Sanna, T., Garulli, A., & Leoni, E. (2016). Proposal for an Enhanced Physical Education Program in the Primary School: Evaluation of Feasibility and Effectiveness in Improving Physical Skills and Fitness. *Journal of Physical Activity & Health*, 13(10), 1025-1034. doi:10.1123/jpah.2015-0694

Dollman, J., Norton, K., & Norton, L. (2005). Evidence for secular trends in children's physical activity behaviour. *British Journal of Sports Medicine*, 39(12), 892-897; discussion 897. doi: 10.1136/bjsm.2004.016675

Donnelly, J. E., Hillman, C. H., Castelli, D., Etnier, J. L., Lee, S., Tomporowski, P., . . . Szabo-Reed, A. N. (2016). Physical Activity, Fitness, Cognitive Function, and Academic Achievement in Children: A Systematic Review. *Medicine & Science in Sports & Exercise*, 48(6), 1197-1222. doi:10.1249/MSS.0000000000000901

Gong, C. D., Wu, Q. L., Chen, Z., Zhang, D., Zhao, Z. Y., & Peng, Y. M. (2013). Glycolipid metabolic status of overweight/obese adolescents aged 9- to 15-year-old and the BMI-SDS/BMI cut-off value of predicting dyslipidemiain boys, Shanghai, China: a cross-sectional study. *Lipids in Health and Diseases*, 12, 129. doi: 10.1186/1476-511X-12-129

Hammami, M. A., Ben Abderrahmane, A., Nebigh, A., Le Moal, E., Ben Ounis, O., Tabka, Z., & Zouhal, H. (2013). Effects of a soccer season on anthropometric characteristics and physical fitness in elite young soccer players. *Journal of Sports Sciences*, 31(6), 589-596. doi: 10.1080/02640414.2012.746721

Harre, D. (1982). *The principles of sports training: introduction to the theory and methods of training*. Sportverlag, Berlin, German.

Heyward, V. H. (1991). *Advanced fitness assessment and exercise prescription*. Human Kinetics Books, 3e edition(2), 1-50.

Hoff, J. (2005). Training and testing physical capacities for elite soccer players. *Journal of Sports Sciences*, 23(6), 573-582. doi: 10.1080/02640410400021252

Hoff, J., & Helgerud, J. (2004). Endurance and strength training for soccer players: physiological considerations.

Sports Medicine, 34(3), 165-180. doi: 10.2165/00007256-200434030-00003

Iivonen, S. K. S., A.; Laukkanen, A. (2015). A review of studies using the Körperkoordinationstest für Kinder (KTK). *European Journal of Adapted Physical Activity*, 8(2).

Iivonen, S. S., Sääkslahti, A., & Laukkanen, A. (2014). Studies using the körperkoordinationstest für (ktk): A review'. *Science & Sports*, 29, 21.

Kamandulis, S., Venckunas, T., Masiulis, N., Matulaitis, K., Balciunas, M., Peters, D., & Skurvydas, A. (2013). Relationship between general and specific coordination in 8- to 17-year-old male basketball players. *Percept Mot Skills*, 117(3), 821-836. doi: 10.2466/25.30.PMS.117x28z7

Kaplan, T., Erkmen, N., & Taskin, H. (2009). The evaluation of the running speed and agility performance in professional and amateur soccer players. *Journal of Strength & Conditioning Research*, 23(3), 774-778. doi: 10.1519/JSC.0b013e3181a079ae

Lago-Penas, C., Rey, E., Casais, L., & Gomez-Lopez, M. (2014). Relationship Between Performance Characteristics and the Selection Process in Youth Soccer Players. *Journal of Human Kinetics*, 40(1), 189-199. doi: 10.2478/hukin-2014-0021

Leger, L. A., & Lambert, J. (1982). A maximal multistage 20-m shuttle run test to predict VO2 max. *European Journal of Applied Physiology and Occupational Physiology*, 49(1), 1-12.

Lyle, M. A., Valero-Cuevas, F. J., Gregor, R. J., & Powers, C. M. (2015). Lower extremity dexterity is associated with agility in adolescent soccer athletes. *Scandinavian Journal of Medicine & Science in Sports*, 25(1), 81-88. doi:10.1111/sms.12162

Mujika, I., Santisteban, J., Impellizzeri, F. M., & Castagna, C. (2009). Fitness determinants of success in men's and women's football. *Journal of Sports Sciences*, 27(2), 107-114. doi: 10.1080/02640410802428071

O'Reilly, J., & Wong, S. H. (2012). The development of aerobic and skill assessment in soccer. *Sports Medicine*, 42(12), 1029-1040. doi: 10.2165/11635120-000000000-00000

Ortega, F. B., Ruiz, J. R., Castillo, M. J., & Sjostrom, M. (2008). Physical fitness in childhood and adolescence: a powerful marker of health. *International Journal of Obesity* (Lond), 32(1), 1-11. doi: 10.1038/sj.ijo.0803774

Paul, D. J., & Nassis, G. P. (2015). Physical Fitness Testing in Youth Soccer: Issues and Considerations Regarding Reliability, Validity and Sensitivity. *Pediatric Exercise Science*, 27(3), 301-313. doi: 10.1123/mc.2014-0085

Pauole, K. M., K.; Garhammer, J.; Lacourse, M.; Rozenek, R. . (2000). Reliability and Validity of the T-Test as a Measure of Agility, Leg Power, and Leg Speed in College-Aged Men and Women. *Journal of Strength & Conditioning Research*, 14(4), 443–450.

Petrigna, L., Karsten, B., Marcolin, G., Paoli, A., D'Antona, G., Palma, A., & Bianco, A. (2019). A Review of Countermovement and Squat Jump Testing Methods in the Context of Public Health Examination in Adolescence: Reliability and Feasibility of Current Testing Procedures. *Frontiers in Physiology*, 10, 1384. doi: 10.3389/fphys.2019.01384

Pojskic, H., Aslin, E., Krolo, A., Jukic, I., Uljevic, O., Spasic, M., & Sekulic, D. (2018). Importance of Reactive Agility and Change of Direction Speed in Differentiating Performance Levels in Junior Soccer Players: Reliability and Validity of Newly Developed Soccer-Specific Tests. *Frontiers in Physiology*, 9, 506. doi: 10.3389/fphys.2018.00506

Stolen, T., Chamari, K., Castagna, C., & Wisloff, U. (2005). Physiology of soccer: an update. *Sports Medicine*, 35(6), 501-536. doi: 10.2165/00007256-200535060-00004

Svensson, M., & Drust, B. (2005). Testing soccer players. *Journal of Sports Sciences*, 23(6), 601-618. doi: 10.1080/02640410400021294

Tabacchi, G., Lopez Sanchez, G.F., Nese Sahin, F., Kizilyalli, M., Genchi, R., Basile, M., Kirkar, M., Silva, C., Loureiro, N., Teixeira, E., Demetriou, Y., Sturm, D.J., Pajaujene, S., Zuoziene, I.J., Gómez-López, M., Rada, A., Pausic, J., Lakicevic, N., Petrigna, L., Feka, K., Ribeiro, A., Alesi, M., & Bianco, A. (2019). Field-Based Tests for the Assessment of Physical Fitness in Children and Adolescents Practicing Sport: A Systematic Review within the ESA Program. *Sustainability*, 11, 1-21. doi:10.3390/su11247187

Trecroci, A., Cavaggioni, L., Caccia, R., & Alberti, G. (2015). Jump Rope Training: Balance and Motor Coordination in Preadolescent Soccer Players. *Journal of Sports Science and Medicine*, 14(4), 792-798.

Vandorpe, B., Vandendriessche, J., Lefevre, J., Pion, J., Vaeyens, R., Matthys, S., . . . Lenoir, M. (2011). The KorperkoordinationsTest fur Kinder: reference values and suitability for 6-12-year-old children in Flanders. *Scandinavian Journal of Medicine & Science in Sports*, 21(3), 378-388. doi: 10.1111/j.1600-0838.2009.01067.x

Walaszek, R., Chwala, W., Walaszek, K., Burdacki, M., & Blaszczuk, J. (2017). Evaluation of the accuracy of the postural stability measurement with the Y-Balance Test based on the levels of the biomechanical parameters. *Acta of Bioengineering and Biomechanics*, 19(2), 121-128.

Wells, K. F. D., E. K. (1952). The Sit and Reach-A Test of Back and Leg Flexibility. Research Quarterly. *American Association for Health, Physical Education and Recreation*, 23(1), 115-118.

Zatsiorsky, V. M. a. K., V.J . (2006). *Science and practice of strength training*. 2nd edition. Human Kinetics, Champaign, Illinois.

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Apart from chapter headings and sub-headings avoid any kind of formatting in the main text of the manuscripts.

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1.6. After Acceptance

After the manuscript has been accepted, authors will receive a PDF version of the manuscripts for authorization, as it should look in printed version of MJSSM. Authors should carefully check for omissions. Reporting errors after this point will not be possible and the Editorial Board will not be eligible for them.

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1.7. Code of Conduct Ethics Committee of Publications

MJSSM is hosting the Code of Conduct Ethics Committee of Publications of the **COPE** (the Committee on Publication Ethics), which provides a forum for publishers and Editors of scientific journals to discuss issues relating to the integrity of the work submitted to or published in their journals.

2. MANUSCRIPT STRUCTURE

2.1. Title Page

The first page of the manuscripts should be the title page, containing: title, type of publication, running head, authors, affiliations, corresponding author, and manuscript information. *See* example:

Transfer of Learning on a Spatial Memory Task between the Blind and Sighted People Spatial Memory among Blind and Sighted

Original Scientific Paper

Transfer of learning on a spatial memory task

Selcuk Akpinar[1], Stevo Popović[1,2], Sadettin Kirazci[1]

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[2]University of Montenegro, Faculty for Sport and Physical Education, Niksic, Montenegro

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S. Popovic
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Narodne omladine bb, 84000 Niksic, Montenegro
E-mail: stevop@ac.me

Word count: 2,980

Abstract word count: 236

Number of Tables: 3

Number of Figures: 3

2.1.1. Title

Title should be short and informative and the recommended length is no more than 20 words. The title should be in Title Case, written in uppercase and lowercase letters (initial uppercase for all words except articles, conjunctions, short prepositions no longer than four letters etc.) so that first letters of the words in the title are capitalized. Exceptions are words like: "and", "or", "between" etc. The word following a colon (:) or a hyphen (-) in the title is always capitalized.

2.1.2. Type of publication

Authors should suggest the type of their submission.

2.1.3. Running head

Short running title should not exceed 50 characters including spaces.

2.1.4. Authors

The form of an author's name is first name, middle initial(s), and last name. In one line list all authors with full names separated by a comma (and space). Avoid any abbreviations of academic or professional titles. If authors belong to different institutions, following a family name of the author there should be a number in superscript designating affiliation.

2.1.5. Affiliations

Affiliation consists of the name of an institution, department, city, country/territory(in this order) to which the author(s) belong and to which the presented / submitted work should be attributed. List all affiliations (each in a separate line) in the order corresponding to the list of authors. Affiliations must be written in English, so carefully check the official English translation of the names of institutions and departments.

Only if there is more than one affiliation, should a number be given to each affiliation in order of appearance. This number should be written in superscript at the beginning of the line, separated from corresponding affiliation with a space. This number should also be put after corresponding name of the author, in superscript with no space in between.

If an author belongs to more than one institution, all corresponding superscript digits, separated with a comma with no space in between, should be present behind the family name of this author.

In case all authors belong to the same institution affiliation numbering is not needed.

Whenever possible expand your authors' affiliations with departments, or some other, specific and lower levels of organization.

2.1.6. Corresponding author

Corresponding author's name with full postal address in English and e-mail address should appear, after the affiliations. It is preferred that submitted address is institutional and not private. Corresponding author's name should include only initials of the first and middle names separated by a full stop (and a space) and the last name. Postal address should be written in the following line in sentence case. Parts of the address should be separated by a comma instead of a line break. E-mail (if possible) should be placed in the line following the postal address. Author should clearly state whether or not the e-mail should be published.

2.1.7. Manuscript information

All authors are required to provide word count (excluding title page, abstract, tables/figures, figure legends, Acknowledgements, Conflict of Interest, and References), the Abstract word count, the number of Tables, and the number of Figures.

2.2. Abstract

The second page of the manuscripts should be the abstract and key words. It should be placed on second page of the manuscripts after the standard title written in upper and lower case letters, bold.

Since abstract is independent part of your paper, all abbreviations used in the abstract should also be explained in it. If an abbreviation is used, the term should always be first written in full with the abbreviation in parentheses immediately after it. Abstract should not have any special headings (e.g., Aim, Results…).

Authors should provide up to six key words that capture the main topics of the article. Terms from the Medical Subject Headings (MeSH) list of Index Medicus are recommended to be used.

Key words should be placed on the second page of the manuscript right below the abstract, written in italic. Separate each key word by a comma (and a space). Do not put a full stop after the last key word. *See* example:

Abstract

Results of the analysis of…

Key words: spatial memory, blind, transfer of learning, feedback

2.3. Main Chapters

Starting from the third page of the manuscripts, it should be the main chapters. Depending on the type of publication main manuscript chapters may vary. The general outline is: Introduction, Methods, Results, Discussion, Acknowledgements (optional), Conflict of Interest (optional), and Title and Abstract in Montenegrin (only for the authors from former Yugoslavia, excluding Macedonians and Slovenes). However, this scheme may not be suitable for reviews or publications from some areas and authors should then adjust their chapters accordingly but use the general outline as much as possible.

2.3.1. Headings

Main chapter headings: written in bold and in Title Case. *See* example:
- ✓ **Methods**

Sub-headings: written in italic and in normal sentence case. Do not put a full stop or any other sign at the end of the title. Do not create more than one level of sub-heading. *See* example:
- ✓ *Table position of the research football team*

2.3.2 Ethics

When reporting experiments on human subjects, there must be a declaration of Ethics compliance. Inclusion of a statement such as follow in Methods section will be understood by the Editor as authors' affirmation of compliance: "This study was approved in advance by [name of committee and/or its institutional sponsor]. Each participant voluntarily provided written informed consent before participating." Authors that fail to submit an Ethics statement will be asked to resubmit the manuscripts, which may delay publication.

2.3.3 Statistics reporting

MJSSM encourages authors to report precise p-values. When possible, quantify findings and present them with appropriate indicators of measurement error or uncertainty (such as confidence intervals). Use normal text (i.e., non-capitalized, non-italic) for statistical term "p".

2.3.4. 'Acknowledgements' and 'Conflict of Interest' (optional)

All contributors who do not meet the criteria for authorship should be listed in the 'Acknowledgements' section. If applicable, in 'Conflict of Interest' section, authors must clearly disclose any grants, financial or material supports, or any sort of technical assistances from an institution, organization, group or an individual that might be perceived as leading to a conflict of interest.

2.4. References

References should be placed on a new page after the standard title written in upper and lower case letters, bold.

All information needed for each type of must be present as specified in guidelines. Authors are solely responsible for accuracy of each reference. Use authoritative source for information such as Web of Science, Medline, or PubMed to check the validity of citations.

2.4.1. References style

MJSSM adheres to the American Psychological Association 6th Edition reference style. Check "American Psychological Association. (2009). Concise rules of APA style. American Psychological Association." to ensure the manuscripts conform to this reference style. Authors using EndNote® to organize the references must convert the citations and bibliography to plain text before submission.

2.4.2. Examples for Reference citations

One work by one author
- ✓ In one study (Reilly, 1997), soccer players…
- ✓ In the study by Reilly (1997), soccer players…
- ✓ In 1997, Reilly's study of soccer players…

Works by two authors
- ✓ Duffield and Marino (2007) studied…
- ✓ In one study (Duffield & Marino, 2007), soccer players…
- ✓ In 2007, Duffield and Marino's study of soccer players…

Works by three to five authors: cite all the author names the first time the reference occurs and then subsequently include only the first author followed by et al.
- ✓ First citation: Bangsbo, Iaia, and Krustrup (2008) stated that…
- ✓ Subséquent citation: Bangsbo et al. (2008) stated that…

Works by six or more authors: cite only the name of the first author followed by et al. and the year

- ✓ Krustrup et al. (2003) studied…
- ✓ In one study (Krustrup et al., 2003), soccer players…

Two or more works in the same parenthetical citation: Citation of two or more works in the same parentheses should be listed in the order they appear in the reference list (i.e., alphabetically, then chronologically)

- ✓ Several studies (Bangsbo et al., 2008; Duffield & Marino, 2007; Reilly, 1997) suggest that…

2.4.3. Examples for Reference list

Journal article (print):

Nepocatych, S., Balilionis, G., & O'Neal, E. K. (2017). Analysis of dietary intake and body composition of female athletes over a competitive season. *Montenegrin Journal of Sports Science and Medicine, 6*(2), 57-65. doi: 10.26773/mjssm.2017.09.008

Duffield, R., & Marino, F. E. (2007). Effects of pre-cooling procedures on intermittent-sprint exercise performance in warm conditions. *European Journal of Applied Physiology, 100*(6), 727-735. doi: 10.1007/s00421-007-0468-x

Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., . . . Bangsbo, J. (2003). The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Medicine and Science in Sports and Exercise, 35*(4), 697-705. doi: 10.1249/01.MSS.0000058441.94520.32

Journal article (online; electronic version of print source):

Williams, R. (2016). Krishna's Neglected Responsibilities: Religious devotion and social critique in eighteenth-century North India [Electronic version]. *Modern Asian Studies, 50*(5), 1403-1440. doi:10.1017/S0026749X14000444

Journal article (online; electronic only):

Chantavanich, S. (2003, October). Recent research on human trafficking. *Kyoto Review of Southeast Asia, 4*. Retrieved November 15, 2005, from http://kyotoreview.cseas.kyoto-u.ac.jp/issue/issue3/index.html

Conference paper:

Pasadilla, G. O., & Milo, M. (2005, June 27). *Effect of liberalization on banking competition*. Paper presented at the conference on Policies to Strengthen Productivity in the Philippines, Manila, Philippines. Retrieved August 23, 2006, from http://siteresources.worldbank.org/INTPHILIPPINES/Resources/Pasadilla.pdf

Encyclopedia entry (print, with author):

Pittau, J. (1983). Meiji constitution. In *Kodansha encyclopedia of Japan* (Vol. 2, pp. 1-3). Tokyo: Kodansha.

Encyclopedia entry (online, no author):

Ethnology. (2005, July). In *The Columbia encyclopedia* (6th ed.). New York: Columbia University Press. Retrieved November 21, 2005, from http://www.bartleby.com/65/et/ethnolog.html

Thesis and dissertation:

Pyun, D. Y. (2006). *The proposed model of attitude toward advertising through sport.* Unpublished Doctoral Dissertation. Tallahassee, FL: The Florida State University.

Book:

Borg, G. (1998). *Borg's perceived exertion and pain scales*: Human kinetics.

Chapter of a book:

Kellmann, M. (2012). Chapter 31-Overtraining and recovery: Chapter taken from Routledge Handbook of Applied Sport Psychology ISBN: 978-0-203-85104-3 *Routledge Online Studies on the Olympic and Paralympic Games* (Vol. 1, pp. 292-302).

Reference to an internet source:

Agency. (2007). Water for Health: Hydration Best Practice Toolkit for Hospitals and Healthcare. Retrieved 10/29, 2013, from www.rcn.org.uk/newsevents/hydration

2.5. Tables

All tables should be included in the main manuscript file, each on a separate page right after the Reference section.

Tables should be presented as standard MS Word tables.

Number (Arabic) tables consecutively in the order of their first citation in the text.

Tables and table headings should be completely intelligible without reference to the text. Give each column a short or abbreviated heading. Authors should place explanatory matter in footnotes, not in the heading. All abbreviations appearing in a table and not considered standard must be explained in a footnote of that table. Avoid any shading or coloring in your tables and be sure that each table is cited in the text.

If you use data from another published or unpublished source, it is the authors' responsibility to obtain permission and acknowledge them fully.

2.5.1. Table heading

Table heading should be written above the table, in Title Case, and without a full stop at the end of the heading. Do not use suffix letters (e.g., Table 1a, 1b, 1c); instead, combine the related tables. *See* example:

- ✓ **Table 1.** Repeated Sprint Time Following Ingestion of Carbohydrate-Electrolyte Beverage

2.5.2. Table sub-heading

All text appearing in tables should be written beginning only with first letter of the first word in all capitals, i.e., all words for variable names, column headings etc. in tables should start with the first letter in all capitals. Avoid any formatting (e.g., bold, italic, underline) in tables.

2.5.3. Table footnotes

Table footnotes should be written below the table.

General notes explain, qualify or provide information about the table as a whole. Put explanations of abbreviations, symbols, etc. here. General notes are designated by the word *Note* (italicized) followed by a period.

- ✓ *Note.* CI: confidence interval; Con: control group; CE: carbohydrate-electrolyte group.

Specific notes explain, qualify or provide information about a particular column, row, or individual entry. To indicate specific notes, use superscript lowercase letters (e.g. [a, b, c]), and order the superscripts from left to right, top to bottom. Each table's first footnote must be the superscript [a].

- ✓ [a]One participant was diagnosed with heat illness and n = 19.[b]n =20.

Probability notes provide the reader with the results of the texts for statistical significance. Probability notes must be indicated with consecutive use of the following symbols: * † ‡ § ¶ || etc.

- ✓ *P<0.05,†p<0.01.

2.5.4. Table citation

In the text, tables should be cited as full words. *See* example:

- ✓ Table 1 (first letter in all capitals and no full stop)
- ✓ ...as shown in Tables 1 and 3. (citing more tables at once)
- ✓ ...result has shown (Tables 1-3) that... (citing more tables at once)
- ✓ ....in our results (Tables 1, 2 and 5)... (citing more tables at once)

2.6. Figures

On the last separate page of the main manuscript file, authors should place the legends of all the figures submitted separately.

All graphic materials should be of sufficient quality for print with a minimum resolution of 600 dpi. MJSSM prefers TIFF, EPS and PNG formats.

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Figures and figure legends should be completely intelligible without reference to the text.

The price of printing in color is 50 EUR per page as printed in an issue of MJSSM.

2.6.1. Figure legends

Figures should not contain footnotes. All information, including explanations of abbreviations must be present in figure legends. Figure legends should be written bellow the figure, in sentence case. *See* example:

- ✓ **Figure 1.** Changes in accuracy of instep football kick measured before and after fatigued. SR – resting state, SF – state of fatigue, *p>0.01, †p>0.05.

2.6.2. Figure citation

All graphic materials should be referred to as Figures in the text. Figures are cited in the text as full words. *See* example:

- ✓ Figure 1
- × figure 1
- × Figure 1.
- ✓ ….exhibit greater variance than the year before (Figure 2). Therefore…
- ✓ ….as shown in Figures 1 and 3. (citing more figures at once)
- ✓ ….result has shown (Figures 1-3) that... (citing more figures at once)
- ✓ ….in our results (Figures 1, 2 and 5)... (citing more figures at once)

2.6.3. Sub-figures

If there is a figure divided in several sub-figures, each sub-figure should be marked with a small letter, starting with a, b, c etc. The letter should be marked for each subfigure in a logical and consistent way. *See* example:

- ✓ Figure 1a
- ✓ …in Figures 1a and b we can…
- ✓ …data represent (Figures 1a-d)…

2.7. Scientific Terminology

All units of measures should conform to the International System of Units (SI).

Measurements of length, height, weight, and volume should be reported in metric units (meter, kilogram, or liter) or their decimal multiples.

Decimal places in English language are separated with a full stop and not with a comma. Thousands are separated with a comma.

Percentage	Degrees	All other units of measure	Ratios	Decimal numbers
✓ 10%	✓ 10º	✓ 10 kg	✓ 12:2	✓ 0.056
× 10 %	× 10 º	× 10kg	× 12 : 2	× .056

Signs should be placed immediately preceding the relevant number.		
✓ 45±3.4	✓ p<0.01	✓ males >30 years of age
× 45 ± 3.4	× p < 0.01	× males > 30 years of age

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Latin names of species, families etc. should be written in italics (even in titles). If you mention Latin names in your abstract they should be written in non-italic since the rest of the text in abstract is in italic. The first time the name of a species appears in the text both genus and species must be present; later on in the text it is possible to use genus abbreviations. *See* example:

- ✓ First time appearing: *musculus biceps brachii*
- ✓ Abbreviated: *m. biceps brachii*

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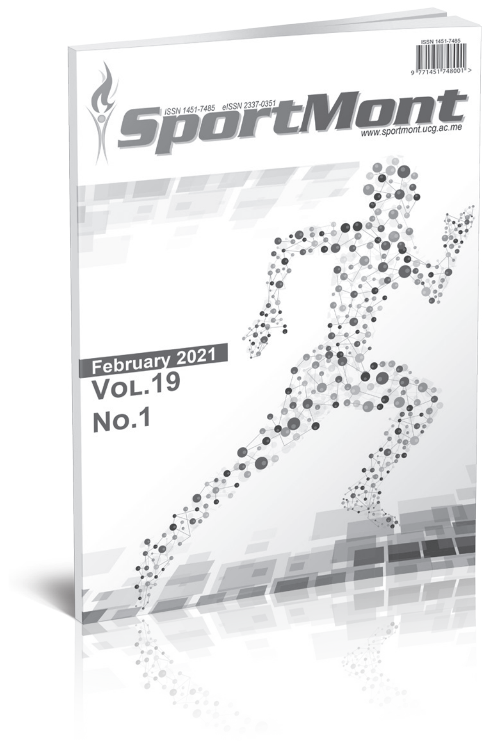

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Publication date: Summer issue – June 2021
Autumn issue – October 2021
Winter issue – February 2022

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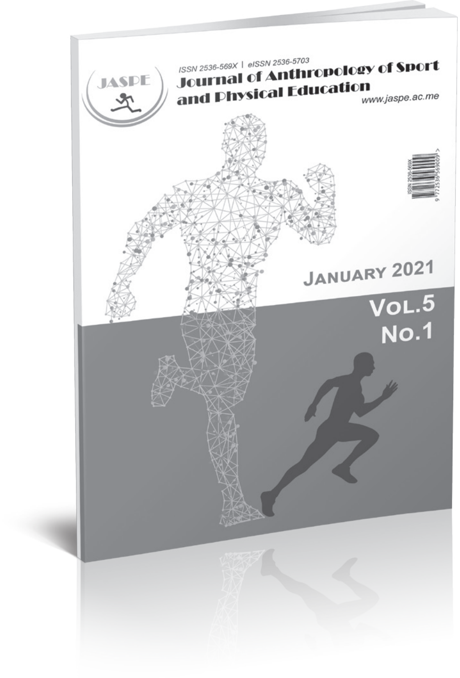
Journal of Anthropology of Sport and Physical Education



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Bojan MASANOVIC, *Editor-in Chief – bojanma@ucg.ac.me*

Publication date: Spring issue – April 2021
Summer issue – July 2021
Autumn issue – October 2021
Winter issue – January 2022

MONTENEGRIN SPORTS ACADEMY

Founded in 2003 in Podgorica (Montenegro), the Montenegrin Sports Academy (MSA) is a sports scientific society dedicated to the collection, generation and dissemination of scientific knowledge at the Montenegrin level and beyond.

The Montenegrin Sports Academy (MSA) is the leading association of sports scientists at the Montenegrin level, which maintains extensive co-operation with the corresponding associations from abroad. The purpose of the MSA is the promotion of science and research, with special attention to sports science across Montenegro and beyond. Its topics include motivation, attitudes, values and responses, adaptation, performance and health aspects of people engaged in physical activity and the relation of physical activity and lifestyle to health, prevention and aging. These topics are investigated on an interdisciplinary basis and they bring together scientists from all areas of sports science, such as adapted physical activity, biochemistry, biomechanics, chronic disease and exercise, coaching and performance, doping, education, engineering and technology, environmental physiology, ethics, exercise and health, exercise, lifestyle and fitness, gender in sports, growth and development, human performance and aging, management and sports law, molecular biology and genetics, motor control and learning, muscle mechanics and neuromuscular control, muscle metabolism and hemodynamics, nutrition and exercise, overtraining, physiology, physiotherapy, rehabilitation, sports history, sports medicine, sports pedagogy, sports philosophy, sports psychology, sports sociology, training and testing.

The MSA is a non-profit organization. It supports Montenegrin institutions, such as the Ministry of Education and Sports, the Ministry of Science and the Montenegrin Olympic Committee, by offering scientific advice and assistance for carrying out coordinated national and European research projects defined by these bodies. In addition, the MSA serves as the most important Montenegrin and regional network of sports scientists from all relevant subdisciplines.

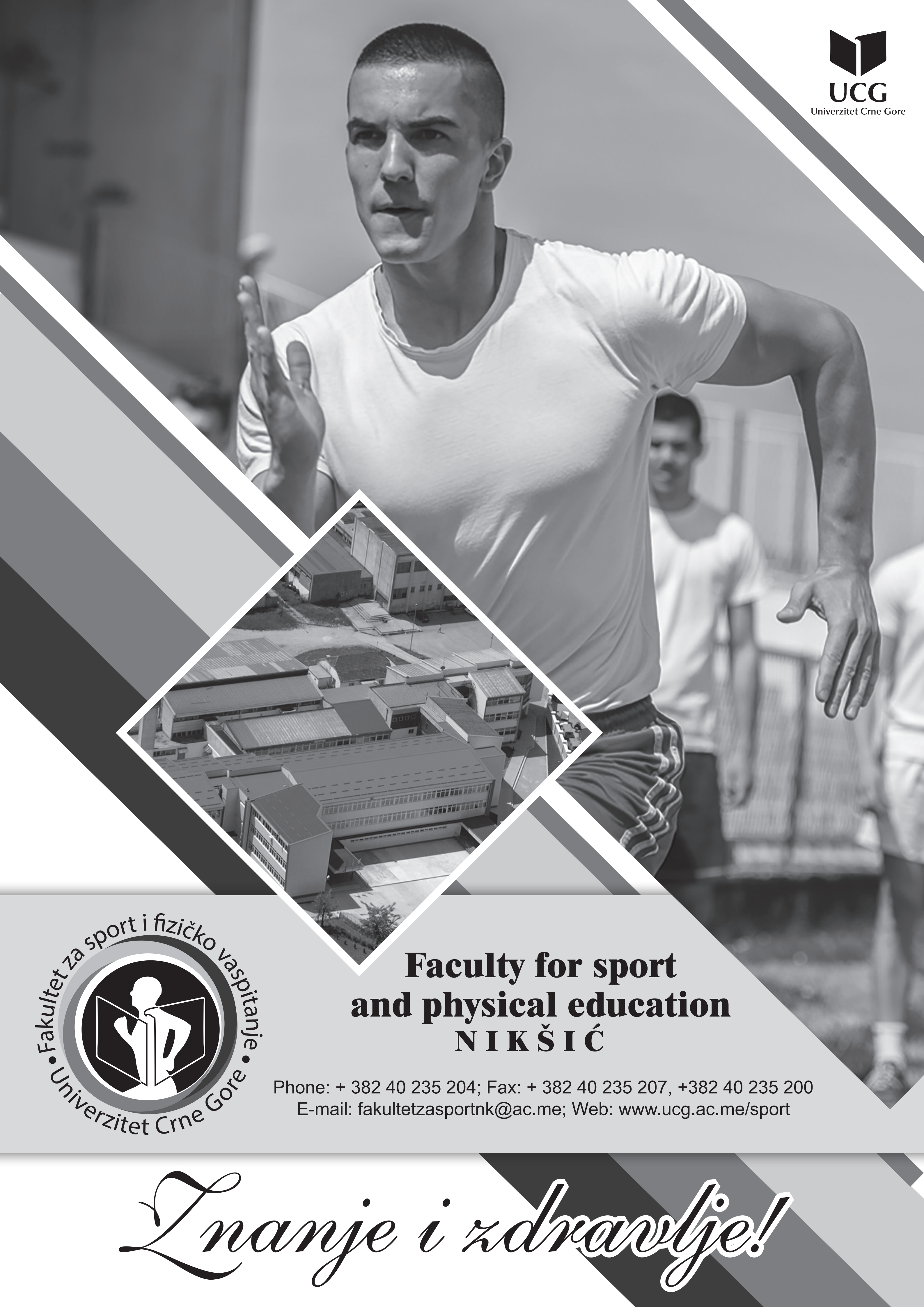
The main scientific event organized by the Montenegrin Sports Academy (MSA) is the annual conference held in the first week of April.

Annual conferences have been organized since the inauguration of the MSA in 2003. Today the MSA conference ranks among the leading sports scientific congresses in the Western Balkans. The conference comprises a range of invited lecturers, oral and poster presentations from multi- and mono-disciplinary areas, as well as various types of workshops. The MSA conference is attended by national, regional and international sports scientists with academic careers. The MSA conference now welcomes up to 200 participants from all over the world.

It is our great pleasure to announce the upcoming 18th Annual Scientific Conference of Montenegrin Sports Academy "Sport, Physical Activity and Health: Contemporary Perspectives" to be held in Dubrovnik, Croatia, from 8 to 11 April, 2021. It is planned to be once again organized by the Montenegrin Sports Academy, in cooperation with the Faculty of Sport and Physical Education, University of Montenegro and other international partner institutions (specified in the partner section).

The conference is focused on very current topics from all areas of sports science and sports medicine including physiology and sports medicine, social sciences and humanities, biomechanics and neuromuscular (see Abstract Submission page for more information).

We do believe that the topics offered to our conference participants will serve as a useful forum for the presentation of the latest research, as well as both for the theoretical and applied insight into the field of sports science and sports medicine disciplines.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MONTENEGRIN SPORTS ACADEMY

8th - 11th April 2021,
Dubrovnik - Croatia