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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 (Web of Science) continues recognizing the development of our journal that is proved by reaching a new Clarivate metric: Journal Citation Indicator (JCI) that is a measure of the average Category Normalized Citation Impact (CNCI) of citable items (articles & reviews) published by a journal over a recent three year period (2019: 0.48; 2020: 0.67). On the other hand, Scopus database also continues recognizing the development of our journal too (CiteScore 2020: 3.00, SJR 2020: 0.320; SNIP 2020: 0.633), while the ongoing tracker is promising a bit worse CiteScore calculation in 2021 (CiteScoreTracker 2021: 2.50; updated on 07 February, 2022) which is scheduled for spring 2022. Although, 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, it won't be necessary as we just received information from Clarivate that all journals in the Web of Science Core Collection™, including those in ESCI and AHCI, are now in the JCR – bringing journals in all 254 categories to the JCR for the first time, which is the best success of Montenegrin Journal of Sports Science and Medicine so far. 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 one more per cents from last preview. Currently, it is on 6% for original research submitted in period 2020-2021 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 (36 days), while the time from submission to publication is a bit increased (66 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

EDITORIAL

MJSSM Editors among Top Scientists Cited Worldwide in Stanford List

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Abstract

In ancient times, science was practiced only by the privileged, primarily because of its poor accessibility. However, the development of ICT has enabled modern man to make science much more accessible to him/her. For that reason, today, there are many more scientists who are trying to change the world for the better with their activities. In the race for new knowledge and original discoveries, scientists want to be better than others. Different metrics are used to measure quality among scientists. Stanford University recently published an updated list of the best scientists in the world, which is considered one of the most prestigious. On a recently published list, three editors of Montenegrin Journal of Sports Science and Medicine: Yousef Saleh Khader, Sergej M. Ostojic and Stevo Popovic have been ranked among the world's top 2% most-cited scientists in 2020 and the purpose of this editorial is to recognize and promote their scientific impact and scientific excellence.

Keywords: *sport science, top scientists, Stanford, World, ranking*

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Introduction

In ancient times, science was practiced only by the privileged, primarily because of its poor accessibility. However, the development of ICT has enabled modern man to make science much more accessible to him/her. For that reason, today, there are many more scientists who are trying to change the world for the better with their activities. In the race for new knowledge and original discoveries, scientists want to be better than others. Different metrics are used to measure quality among scientists. One of the metrics significantly used to assess scientific impact and scientific excellence is citation. However, citations, although widespread, have many limitations. Namely, it is not enough to count quotes, but it is necessary to assess what quotes mean, that is, to know how they are interpreted correctly and to know how they can be misinterpreted. It is very important to emphasize that there are several different databases of citations, and they are: "Google Scholar", "Scopus", "Web of Science" and others. The "Google Scholar" database gathers the entire Internet in one place and systematically processes all documents that have a scientific character, while the quality of these documents is not taken into account that is a huge limitation. On the other hand, the "Scopus" and "Web of Science" databases operate on a different principle, they only collect documents that have gone through an evaluation process and have a certain level of quality. Therefore, it is very important to overcome certain technical and essential problems and to ensure an objective ranking of scientists around the world when it comes to assessing scientific impact and scientific excellence

Stanford University recently published an updated list of the

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best scientists in the world (Baas et al., 2021), which is considered one of the most prestigious. Why? It is based on bibliometric information contained in one of the most relevant "Scopus" databases, and has processed more than 180,000 scientists (out of 8 million active scientists worldwide), from 22 scientific disciplines and 176 subfields. Added value is also a fact that a research team, led by Professor John Ioannidis, offered an objective solution to overcome the limitations outlined in the previous paragraph and devised indicators that included information on citations, an individual's scientific research output, co-authorship and a composite indicator (Ioannidis et al., 2016). On a recently published list, three editors of Montenegrin Journal of Sports Science and Medicine: Yousef Saleh Khader, Sergej M. Ostojic and Stevo Popovic have been ranked among the world's top 2% most-cited scientists in 2020 and the purpose of this editorial is to recognize and promote their scientific impact and scientific excellence.

Contribution to the field

As pointed out in the previous chapter, science has progressed drastically from ancient times to the present day. One of the greatest thinkers of modern times, Stephen Hawking, also spoke about the development of science. As early as the beginning of the 21st century, he pointed out that he believed that the coming century would be "the century of complexity" (cited in Hausken-Sutter, 2021). What exactly is that supposed to mean? Namely, speaking about the way that science will develop during the 21st century, Stephen Hawking unequivocally pointed to the fact that scientists will increasingly concentrate on scientific ideas that increasingly rely on in theories of chaos, complex systems, fractal geometry, nonlinear dynamics, and quantum mechanics (Newell, 2001). He also pointed out that in this way, scientists will be able to better understand the phenomena that characterize dynamism and unpredictability, then multidimensionality and interconnectedness, where he classified human behaviour as one of the most important anthropological issues of modern times (Nevell, 2001; Salmon & McLean, 2020). After a little more than two decades since Hawking's prediction, it is clear that his theses were correct, primarily because the theory of complexity is very popular today. Interestingly, it is particularly important in the field of sports and health sciences, and that addressing these very important issues when it comes to healthy lifestyles requires the integration of knowledge from different fields (Burvitz et al., 1994; Terpstra et. al., 2010). As early as the end of the 20th century, there was an initiative that promoted research that integrated knowledge from several different fields (Burvitz et al., 1994), as research questions that are too broad and so complex that answers could be sought, exclusively in the field of one scientific discipline. In this way, we come to interdisciplinary research in which different knowledge, or disciplinary knowledge, is integrated through the construction of a more comprehensive understanding of the phenomenon being studied (cited in Hausken-Sutter, 2021). Hence, sports sciences gain importance because teams of disciplinary experts from different fields are formed to monitor the pragmatic research process, each from its own disciplinary field, while the conclusions and recommendations for further research have interdisciplinary character.

Sports sciences as an academic field are a relatively young field, which emerged at the end of the 20th century on the basis of monodisciplines such as pedagogy, sociology, psychology, but also physiology, anatomy, biology, as well as economics, medicine and others. Although physical education as a forerunner of sports sciences dates back to earlier times, the emergence of sports sciences as an academic field is associated with the creation of a larger number of subdisciplines in the subject area. From its inception until today, sports sciences are developing rapidly and this is reflected in the fact that "over 25,000 is published annually in the field of sports sciences, and it is equal as in most natural and technical science disciplines (Popovic, 2018)". Thus, sports sciences, like most other scientific fields, are also developed on the principles of recognizing creativity and modern thinking, where no one theory or discipline should be valued in relation to another (cited in Hausken-Sutter, 2021). These changes are also visible in the example of Montenegrin Journal of Sports Science and Medicine (MJSSM), which, over the last ten years, has developed into a modern and high-quality interdisciplinary journal in the field of sports sciences and medicine. Namely, this fact is confirmed by the latest Stanford list of the best scientists in the world for 2020, which includes three MJSSM editors. Yousef Saleh Khader was ranked at 10,251 place among the best scientists in the world for 2020, while Sergej M. Ostojic was ranked on 27,132 and Stevo Popovic was ranked on 145,073 place (Baas et al., 2021). It is interesting that all three mentioned editors belong to different monodisciplines. Namely, Yousef Saleh Khader works as a Professor of Epidemiology and Biostatistics and Sports Scientist at the Department of Community Medicine, Jordan University of Science and Technology and took his doctoral degree in Biostatistics (his personal "Scopus" profile is print screened in Picture 1; Yousef Saleh Khader, 2021); Sergej M. Ostojic works as a Professor of Biomedical Sciences and Sport Scientist at the Laboratory for Applied Physiology and Nutrition at the Faculty of Sports and Phys-

Figure 1. Personal "Scopus" Profile of Yousef Saleh Khader

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Figure 2. Personal "Scopus" Profile of Sergej M. Ostojic

ical Education, University of Novi Sad and took his doctoral degree in Medicine (his personal "Scopus" profile is print screened in Picture 2; Sergej M. Ostojic, 2021); while Stevo Popovic works as an Associate Professor of Sport Science and Sport Scientist at the Faculty for Sport and Physical Education at the University of Montenegro and took his doctoral degree in Sport Management (his personal "Scopus" profile is print screened in Picture 3; Stevo Popovic, 2021). Thus, MJSSM is a journal founded with the idea of developing the interdisciplinarity of sports sciences and brings together all scientists who aim to contribute to interdisciplinary teamwork with a holistic approach to sports and physical activity as well as all related areas.

Figure 3. Personal "Scopus" Profile of Stevo Popovic

Conclusion

From all that has been mentioned so far, the fact is that interdisciplinarity is an important element of Sports Sciences. Interdisciplinarity is characterized by certain "forms": scientific, organizational, academic and social form (Camy et al, 2017), and all four forms must be recognized by a particular subject in order to be labelled as interdisciplinary. MJSSM strives to be an interdisciplinary journal in the field of Sports Sciences, and to cover all subdisciplines belonging to Sports Sciences and Medicine, such as Social Sciences and Humanities, Sports Medicine and Physiology, and Biomechanics and Neurophysiology, three areas that are most visible internationally (Champely et al., 2017). Although the sports sciences have strengthened as a separate academic field, it is still very difficult to talk about the clear boundaries that this field covers. Debates are still ongoing, especially in countries where Sports Sciences are less developed. The situation in Montenegro (where MJSSM is located) is better from year to year, primarily due to the rapid progress of the MJSSM, but also the Annual Scientific Conference of the Montenegrin Sports Academy and the growing number of young sports scientists who mature and become scientists recognized on the international scene. However, the biggest contribution was made by the last ranking list, which included three MJSSM editors, thus confirming the strong interdisciplinary character of MJSSM and the quality of human staff, which promise further growth of quality and recognition of MJSSM on the international scene.

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ORIGINAL SCIENTIFIC PAPER

Effects of Different Levels of Fatigue on Vertical Jump Performance, Vertical Stiffness, and Intralimb Coordination

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Abstract

This study aimed to investigate the acute effects of different levels of muscular fatigue on vertical jump performance, vertical stiffness, and intralimb coordination. Seventeen physically active men performed two fatigue protocols (low volume and high volume) composed of continuous vertical jumps on separate weeks. Jump height, vertical stiffness, and intralimb coordination were measured during countermovement vertical jumps prior to and immediately following the fatigue protocols. The jumps were performed on a force plate and filmed with high-speed cameras. The continuous relative phase was calculated as a measure of intralimb coordination. Mixed-model ANOVA was used to compare the variables between conditions and times. The fatigue index was greater in the high-volume protocol (27±12%) than in the low-volume protocol (16±7%). Jump height decreased ($p \leq 0.01$) after the high-volume protocol. Vertical stiffness decreased ($p=0.05$), and the continuous relative phase of thigh-shank coupling in the ascent phase of countermovement jumps increased ($p=0.04$) after both protocols. In conclusion, jump performance was only affected by higher fatigue indexes, while vertical stiffness and intralimb coordination were affected similarly irrespective of the fatigue levels.

Keywords: *stretch-shortening cycle, jump height, spring-mass model, continuous relative phase, motor control, biomechanics*

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Introduction

Repetitive, intense exercises involving the stretching-shortening cycle (SSC), such as vertical jumps, generate a high rate of mechanical work and consequently induce substantial muscular fatigue (Komi, 2000). It has been shown that this kind of exercise can lead to acute and long-term impairments of muscle function, which directly affect task performance (Byrne et al., 2004; Nicol et al., 2006). Generally, SSC performance impairment has been associated with changes in parameters related to the motor control of vertical jumps, such as lower limb stiffness and coordination of joints or body segments (Dal Pupo et al., 2013; Rodacki et al., 2002).

Many studies in the literature investigate the effects of fatigue on lower limb stiffness and coordination, but the re-

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sults are inconsistent. Some studies have shown that lower limb stiffness remains unchanged with fatigue (Kuitunen et al., 2007; Mudie et al., 2016; Padua et al., 2006), while decreased stiffness has also been reported in the literature (Dal Pupo et al., 2013; Horita et al., 1996; Lazaridis et al., 2018; Zhang et al., 2018). These alterations have been attributed to a reduction in the pre-activation and the stretching reflex of certain muscles responsible for stiffness regulation (Kuitunen et al., 2002; Lazaridis et al., 2018). In terms of performance, maintaining an optimal level of stiffness is required for the effective use of the elastic energy in the SSC function; however, stiffness reduction with fatigue observed in some studies has been suggested as a protective neural mechanism against injuries that may occur upon high ground impact (Hughes & Watkins, 2008).

Similar results have been observed for intralimb coordination under SSC fatigue conditions. Changes in the coordination of the lower limbs due to fatigue have been observed as a compensation of the motor control system, aiming to maintain task performance (Dal Pupo et al., 2013; James et al., 2006; Lazaridis et al., 2018; Madigan & Pidcoe, 2003) or as a protective mechanism against injuries (Hughes & Watkins, 2008; Madigan & Pidcoe, 2003). In contrast, other studies have shown that coordination does not change even under fatigue conditions due to the existence of a pre-programmed coordination pattern, which maintains the execution of movement through fixed neural commands (Rodacki et al., 2001).

It is known that muscular fatigue is task-dependent; thus, factors such as the type of muscle contraction and the workload training (volume and intensity) may directly influence the response to a bout of fatiguing exercise (Enoka & Stuart, 1992; Kuitunen et al., 2007; Nicol et al., 2006). Generally, more intense or longer exercises (e.g., jump protocols of high volume) causes more fatigue and consequently induce greater impairment in muscle function when compared to less intense or lower volume exercises (Nicol et al., 2006), but this fatigue response seems to be more evident in neuromuscular performance (i.e., reduction in strength/power production capacity). In contrast, the fatigue effects on movement control parameters (e.g., stiffness or segmental coordination) have been suggested as non-uniform in different workloads (Lazaridis et al., 2018) and are not well understood in the literature. Identifying how movement control and performance parameters are affected when athletes are exposed to different workloads (e.g., during training or competition), for example, is particularly important in determining recovery time aiming to maximize performance and avoiding possible injury risks (McMahon et al., 2012; Rodacki et al., 2002).

Thus, the objective of this study was to investigate the acute effects of different muscular fatigue levels on vertical jump performance, vertical stiffness, and intralimb coordination. We hypothesize that there will be changes in jump performance and parameters related to the movement control (i.e., vertical stiffness and intralimb coordination) but depending on the fatigue levels.

Methods

Study design

This study has a crossover design in which participants performed two fatigue protocols using continuous vertical jumps (low-volume and high-volume protocols) on separate days. Dependent variables (jump height, vertical stiffness, and continuous relative phase) were measured in the countermovement jump prior to and immediately following the fatigue protocols. The participants performed both protocols, the low-volume followed by the high-volume protocol, separated by a one-week interval.

Participants

Seventeen healthy male adults (age: 26.8±3.3 years, body mass: 79.3±11.5 kg, height: 181.2±6.4 cm, body fat percentage: 13.2±4.4%) volunteered to participate in the study. The sample size was defined a priori by taking jump performance as a reference variable (GPOWER® software) given α=0.05, expected power of 0.8 and moderate effect size (0.5). Participants practiced physical exercises (strength training, running and/or sports involving jumps) three to five times a week, for at least one year and had no injuries or pathologies that would preclude maximum effort in the tests. It was required that participants did not perform physical exercises involving the lower limbs 24 h prior to testing. The experiments were performed in accordance with the ethical standards of the Helsinki Declaration. After an explanation of the procedures, all the participants signed a consent form to participate in the research, which was approved by the ethics committee of the Federal University of Santa Catarina, and guaranteed their rights and anonymity (CAAE= 87443318.9.0000.0121).

Procedures

At the first visit, participants were familiarized with the jump procedures, and anthropometric measurements were taken to assess the fat percentage (stature, body mass, skinfolds) and kinematic processing (lengths and diameters of the lower limbs). Participants returned on the second day to perform the first fatigue protocol. First, they responded to a perceived exertion scale (Foster et al., 2001) of magnitude 0-10 (0 - no effort; 10 - maximal effort) to monitor rest. Participants performed a warm-up composed of 10 minutes on a cycle ergometer at 90 W. Next, reflective markers (14 mm) for kinematic analysis were placed on the right side of the body on the following anatomical landmarks: acromion, major trochanter, anterior superior iliac spine, posterior superior iliac spine, medial thigh, epicondyle lateral femoral, medial leg, lateral malleolus, calcaneus, and proximal phalanx of the hallux. Then, participants performed three maximal countermovement jumps under pre-fatigue conditions (baseline) on two force platforms (AMTI® OR6-7-OP-2000, USA; 2000 Hz). They started the jump from a static standing position and were instructed to perform a countermovement followed by a rapid and vigorous extension of the lower limb joints, maintaining their trunk as vertical as possible with their hands on their hips. The participants were then instructed to jump as high as possible, maintaining one foot on each platform prior to take-off and after landing. Immediately following the fatigue protocol, the participants performed three maximal countermovement jumps to represent the post-fatigue condition. All pre- and post-fatigue jumps were filmed (VICON®, MX systems, UK; 200 Hz) for kinematic analysis of movement. At the end of the test session, participants respond to a perceived exertion scale, referring to the total effort applied to perform the fatigue pro-

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tocol. After a minimum of seven days, the subjects returned to the laboratory to perform the fatigue protocol with higher volume. This recovery interval was based on previous studies suggesting that 72 to 96 h are enough to recover after SSC fatiguing tasks (Byrne & Eston, 2002; Byrne et al., 2004). In addition, we evaluated muscle soreness before starting the higher-volume protocol using a visual scale (0-10). Soreness values were verified in quadriceps, hamstring, gluteal, and gastrocnemius of 0.0, 0.1, 0.1, and 0.1, respectively, suggesting muscle recovery.

Fatigue protocol

Two vertical jump protocols were used to induce fatigue: the low-volume protocol was composed of seven sets of 10 continuous jumps; the high-volume was composed of 14 sets of 10 continuous jumps. The interval between sets was one minute for both protocols. Our protocols were based on a jumping protocol previously established for inducing SSC fatigue composed of 10 bouts of 10 countermovement jumps (Byrne et al., 2004; Lazaridis et al., 2018; Twist & Eston, 2005). In the present study, we slightly reduced the number of bouts to seven for the low-volume protocol and then doubled that number for the high-volume protocol. Our goal was to have a protocol with twice the volume of the other protocol. We verified in a pilot study that both protocols induced fatigue, but with higher levels in the high-volume protocol than in the low-volume protocol. During the jumps, participants were asked to maintain their trunk as vertical as possible, with their hands on their hips, and with a knee angle of 90° at the end of the descent phase of the jump. The fatigue protocols were performed on a piezoelectric force platform (Kistler® Quattro Jump, 9290 AD, Switzerland; 500 Hz). During vertical jumps, it is natural that imbalances occur, and this platform provides a satisfactory space ($1m^2$) for efficient and safe testing. The participants received verbal encouragement during the protocols to perform all the jumps with the maximum intensity. The fatigue index was calculated as follows in Equation 1 (Dal Pupo et al., 2013), taking into consideration the power output (force multiplied by velocity) during the propulsive phase of the jumps.

$$\text{Fatigue Index} = \left(\frac{\text{PMEAN}_{4J} - \text{PMEAN}_{\text{END}4J}}{\text{PMEAN}_{4J}}\right) * 100 \quad \text{(Eq. 1)}$$

Where PMEAN_{4J} is the average power of the first four jumps, and PMEANEND_{4J} is the average power of the last four jumps.

Data analysis and dependent variables

Three-dimensional kinematics of the movement were obtained during the countermovement jumps using a system with eight high-speed integrated cameras (VICON®, MX systems, UK; 200 Hz), which performed the identification of reflective markers through infrared illumination. The system was calibrated and synchronized with the AMTI® force platforms. The three-dimensional coordinates of the reflective markers were filtered using a fourth-order Butterworth low-pass filter with a cut-off frequency of 10 Hz, determined from spectral analysis, following which the reconstruction of the countermovement jumps was done using the plug-in-gait model of the Nexus® software (VICON system®).

The performance in countermovement jump (jump height) was obtained using kinematic analysis; it was considered the highest vertical displacement of the reflective marker placed on the trochanter (Dias et al., 2011). Ground reaction force data obtained during the jumps were filtered using a low-pass, fourth-order Butterworth filter with a cut-off frequency of 10 Hz, determined from spectral analysis. Vertical stiffness was determined by the spring-mass model in the landing phase of the countermovement jump, by the quotient between the peak vertical ground reaction force during the landing phase and the vertical displacement of the centre of mass, determined by the double integration of ground reaction force (Serpell et al., 2012).

From the coordinates of the markers of interest, the segmental angles of the trunk, thigh, and shank (formed between the respective segments and a horizontal plane) were determined for the intralimb coordination analysis. The continuous relative phase (CRP) was calculated to assess the coordination between segments (Dal Pupo et al., 2013; Hamill et al., 1999). The calculation of CRP followed four steps: obtaining the phase diagram, normalizing the phase diagram, obtaining the phase angle, and obtaining the continuous relative phase. For full information on the calculation of CRP, see Hamill et al. (1999). CRP was analysed on the right side of the body for the thigh-trunk and thigh-shank couplings. The CRP was calculated in the descent (i.e., from the moment when the centre of mass velocity became negative until zero) and ascent (i.e., from the moment when the centre of mass velocity became positive until take-off) phase of the countermovement jump. The root mean square was calculated to represent the CRP of each coupling in each phase and used for statistical analysis. CRP values close to 0° indicate that the segments are more in phase, while values close to 180° indicate that the segments are more out of phase. An algorithm implemented in MatLab® software (The MathWorks, Inc®, USA) was used to obtain all kinematic data.

Statistical analysis

Data are presented as mean ± standard deviation. A mixed-model analysis of variance (ANOVA) was used to compare the variables between conditions (low and high volume) and within the times (before vs. after). The sphericity of the data was tested (Mauchly's Test) and corrected (Green-house Geiser) when necessary. The significant P-value adopted was $p \leq 0.05$. Statistical procedures were performed using the Statistical Package for Social Sciences software (v. 17.0, IBM Co., USA).

Results

The fatigue index was greater in the high-volume protocol (27.0±11.8%) than in the low-volume protocol (15.8±7.0%) (ES=1.51). Consequently, the rate of the perceived exertion scale of the low-volume protocol (4.8±1.5) was inferior (ES=1.69) to that of the high-volume protocol (7.5±1.4).

Jump height showed the interaction between time and protocol (F=5.80; p=0.02). Post-hoc analysis revealed a decrease in jump height (Figure 1a) after the high-volume protocol (p<0.01), while no change was observed after the low-volume protocol (p=0.3). No interaction between time and protocols was obtained for vertical stiffness (F=0.46; p=0.50). However, an effect was visualized in time (F=4.09; p=0.05), indicating that vertical stiffness decreased after both protocols (Figure 1b).

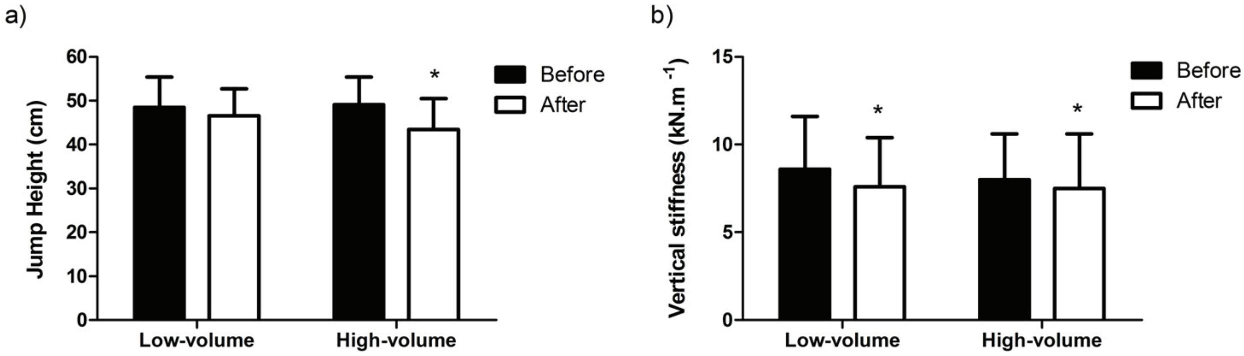

Figure 1. Jump height (panel A) and vertical stiffness (panel B) before and after the low-volume and high-volume protocols. * indicate difference from before-condition

For the intralimb coordination, there was no interaction time vs protocol for thigh-trunk coupling in the descent (F=0.55; p=0.46) or ascent phase (F=0.11; p=0.73), nor time effect (descent phase: F=0.16, p=0.69; ascent phase: F=1.07, p=0.31) or protocol (descent phase: F=0.06, p=0.81; ascent phase: F=0.01, p=0.95). Similarly, thigh-shank coupling did not present time x protocol interaction for descent (F=1.52; p=0.23) and ascent phase (F=0.18; p=0.67). However, it was verified time effect (F=4.43, p=0.04) of CRP thigh-shank during the ascent phase of movement, indicating an increase when comparing before vs. after both protocols. The results from the intralimb coordination can be seen in Figure 2.

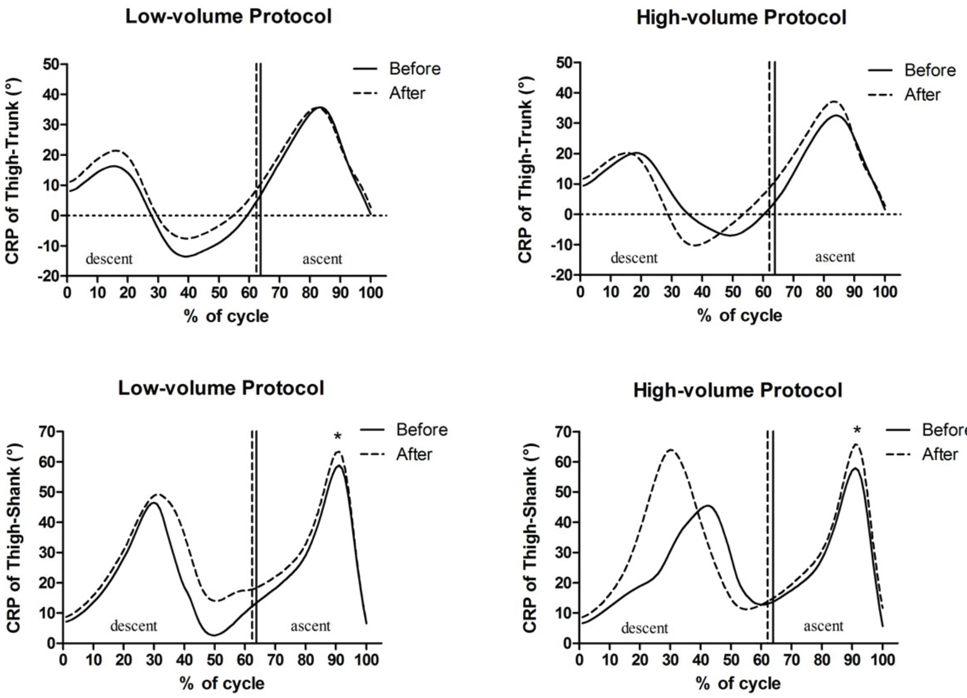

Figure 2. Intralimb coordination (CRP) of thigh-trunk and thigh-leg couplings, for both protocols, during ascent and descent phases of countermovement jump. CRP - continuous relative phase, * indicate difference form before-condition. The vertical lines indicate the transition from phase one for phase two of movement.

Discussion

This study aimed to investigate the acute effects of different levels of muscular fatigue on vertical jump performance, vertical stiffness, and intralimb coordination. It was observed that by doubling the volume of the fatigue protocol while maintaining the same effort (i.e., maximum jumps), the fatigue level increased from 16.0% to 27.0%. The main findings indicate that jump performance was affected only by higher fatigue indexes, while vertical stiffness and intralimb coordination were similarly affected irrespective of the levels of fatigue. Thus, the main hypothesis of this study was accepted only for jump performance.

It is known that the high mechanical stress produced by SSC movements induces acute fatigue, which is commonly related to the accumulation of metabolites, energy depletion, and changes in calcium release/reabsorption (Sahlin, 1992; Williams & Klug, 1995). This results in an impairment of muscle function (Nicol et al., 2006), which consequently may explain the decrease in jump height and vertical stiffness immediately following the fatiguing protocols. However, changes in jump performance seem to occur only when greater mechanical stress is imposed, as seen in the high-volume protocol. Nicol et al. (2006) determined that sometimes exercises with low fatigue indexes reveal facilitation of performance, whereas

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only tests involving high-intensity maximal or near-maximal tests reveal performance deterioration more clearly.

For vertical stiffness, it was observed that SSC fatigue induced a similar decrease immediately following both protocols, suggesting that acute changes in stiffness are not related to the fatigue levels. Most studies with a similar design involving vertical jumps have reported a decrease in vertical and lower limb stiffness after fatigue (Dal Pupo et al., 2013; Horita et al., 1996; Kuitunen et al., 2002; Kuitunen et al., 2007; Lazaridis et al., 2018), although they did not assess or discuss the influence of different levels of fatigue. The decrease in stiffness has been attributed to factors such as a reduction in pre-activation, and alterations in stretching reflex of the triceps sural and knee extensor muscles. These changes may affect the braking capacity of the movement, allowing for greater excursion of movement and consequently decreasing stiffness (Dal Pupo et al., 2013; Kuitunen et al., 2002; Kuitunen et al., 2007; Lazaridis et al., 2018). Lazaridis et al. (2018), Hughes and Watkins (2008), and Dal Pupo et al. (2013) suggest that alterations can occur as a protective mechanism against injury.

The intralimb coordination in the thigh-trunk (in both phases of movement) and thigh-shank (descent phase) couplings did not change after any of the fatigue protocols. The absence of changes in coordination at fatigue conditions has been attributed to the presence of a pre-programmed "common drive", which is difficult to change and that guides the muscle activation and, consequently, the coordination, maintaining the movement pattern through fixed neural commands, even under fatigue conditions (Rodacki et al., 2001). However, we verified that thigh-shank coupling CRP values increased after both protocols, indicating that the movement between the segments became more out of phase after fatigue. Although the thigh-trunk coupling generates important angular moments during a vertical jump (Gheller et al., 2015), the changes observed only in thigh-shank coupling suggest that the muscles around the knee joint are more affected by fatigue. The modulation of coordinative patterns after a fatiguing activity has been suggested as a compensation of the motor control system in an attempt to maintain the performance of the task despite decreased force production (Dal Pupo et al., 2013; Madigan & Pidcoe, 2003). Dal Pupo et al. (2013) suggest that the presence of fatigue or even the modulation of stiffness may influence muscle spindles (and consequently on proprioceptors), which would send afferent feedback signals to the central nervous system to rearrange the coordination pattern of the segments. Moreover, changes in coordination are also speculated as a protective mechanism against injuries, aiming to increase the stability of the limbs or even decrease the ground reaction forces experienced (Hughes & Watkins, 2008; Madigan & Pidcoe, 2003). In addition, the changes to the CPR thigh-shank coupling occurred during the ascent phase of the countermovement jump, which is considered the most determinant for jump performance development (Dal Pupo et al., 2012; Kirby et al., 2011), reinforcing that changes in coordination may have occurred to maintain the vertical jump performance.

The results showed that the fatigue effect was task-dependent (different volumes) for jump performance, in which longer exercise caused more fatigue and consequently induced greater impairment in muscle function (Enoka & Stuart, 1992; Nicol et al., 2006); however, this "linear" response was not evident for motor control parameters, such as vertical stiffness and intralimb coordination. Both vertical stiffness and CRP of thigh-shank coupling had similar changes after the fatigue protocols (i.e., different volumes induced the same changes). According to our results, it seems to exist a minimum fatigue threshold at which these changes occur, provoking the same alterations independent of the fatigue index. Nicol et al. (2006) suggest that in maximal exercises a neural attempt of protection of the fatigued muscle, which does not occur in less fatiguing exercises, may exist. Thus, it can be speculated that the similar effects visualized after both protocols are related to this protective mechanism acting during the high-volume protocol (maximal exercises) but not during the low-volume protocol.

The present study has limitations. The evaluations post-fatigue were conducted with the shortest possible interval after the application of the protocol; however, the time between the completion of the protocol and the evaluation was on average 1 minute and 20 seconds. This may have allowed some level of recovery, influencing the results. In addition, due to methodological limitations, it was not possible to compose a sample of athletes. Thus, although the participants in the present study are physically active, it is difficult to generalize the results to an athlete population since the neuromuscular responses to fatigue could be different due to the level of training. Further studies with a similar theme, involving a population of athletes, are encouraged.

In conclusion, only the high-volume fatigue protocol, which induced a high rate of perceived exertion and fatigue index, was able to decrease the jump performance. In contrast, the decrease in vertical stiffness and in the intralimb coordination of thigh-shank coupling occurred after both protocols, suggesting that changes is these parameters related to movement control are irrespective of the fatigue levels. From a practical point of view, the results of the present study may be important throughout a competition or match when the fatigue is progressive. If we consider, for example, applying our results to a football match, the player will only lose performance significantly after increased levels of accumulated fatigue, probably at the end of the match. However, greater fatigue did not necessarily lead to more commitment in the coordination pattern and vertical stiffness. This suggests that already with low levels of fatigue, changes in stiffness and coordination may occur, probably to keep the control of movement to maintain performance and as a protective neural mechanism against injuries that may occur upon high impact with the ground.

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ORIGINAL SCIENTIFIC PAPER

Differences in the Most Demanding Scenarios of Basketball Match-Play between Game Quarters and Playing Positions in Professional Players

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Abstract

The purpose of this study was to compare the most demanding scenarios (MDS) encountered by professional basketball players across game quarters and playing positions during official match-play. Ten professional basketball players were monitored during 11 matches using a local positioning system. Peak physical demands were measured via total distance, distance >18 and >21 km·h^{-1}, number of sprints >18 and >21 km·h^{-1}, and number of accelerations and decelerations >2 and >3 m·s^{-2} captured over 30, 60, 120, 180, and 300-s rolling averages. Linear mixed models and effect sizes (ES) were used to compare MDS encountered between game quarters and playing positions. Between Quarters 1 and 2, there was a reduction in the total distance (ES = 0.64-1.39) for all playing groups along with a reduction in distance >21 km·h^{-1} in centres (ES = 0.77-0.81) and a reduction in accelerations and decelerations >2 m·s^{-2} in guards (ES = 0.66-0.78) across longer sample periods (180-300-s). Between Quarters 1 and 4, reductions in the total distance were evident for forwards and centres (ES = 0.64-0.91) as well as distance and sprints >21 km·h^{-1} in centres (ES = 0.64-0.97). Regarding positional differences, guards and forwards covered a higher total distance than centres across most quarters and sample periods (ES = 0.22-1.44). Our data suggest a decrease in MDS with game progression in basketball. In addition, MDS appear to be duration-specific and position-dependent in basketball. Therefore, practitioners should consider these differences in MDS based on game quarters and positional demands to optimise individual and team performance.

Keywords: *team sport, local positioning system, load, player monitoring, worst-case scenarios*

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Introduction

Basketball is an intermittent, indoor court-based team sport where high-intensity movements, such as changes of direction, accelerations, decelerations, and jumps, are completed amongst periods of rest (Narazaki et al., 2009; Stojanović et al., 2018). Due to the demanding nature of basketball, mon-

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itoring the physical (external load) and physiological (internal load) demands encountered by players is of critical importance for practitioners in order to promote positive performance-based training adaptations which leave players well-prepared for official games (Sansone et al., 2020). External load is particularly important from a practical perspective as practitioners can directly manipulate it to bring about the desired adaptations in players. Consequently, a detailed understanding of the external loads encountered by players during games is crucial in prescribing and effectively manipulating training.

During basketball match-play, activity durations are highly variable given the frequent stoppages (e.g., free throws, time-outs) encountered. Additionally, these temporal sequences in activity requirements tend to occur randomly, as evidenced by very long periods (e.g., > 120 s) of continuous playing time with different stoppage durations (Salazar & Castellano, 2020). Given this variability in activity duration and playing time, assessing intensity in basketball is necessary when monitoring external load as it is less dependent on duration than measures capturing total load (volume). However, quantifying only average intensity across total games fails to detect passages of higher physical demands known as most demanding scenarios (MDS) (Vázquez-Guerrero & Garcia, 2020). Recent research in basketball demonstrated that when assessing the MDS during different time windows, players are exposed to intensities much greater than the intensities previously reported using game averages (Fox et al., 2020; Vázquez-Guerrero et al., 2020)

Several studies have assessed the physical demands encountered by basketball players across entire games (Russell et al., 2020). However, this approach does not give a complete picture of fluctuations in physical demands across games, such as during individual game quarters. In this regard, the knowledge of the physical demands throughout all quarters is essential in understanding how a player's physical performance fluctuates relative to the accumulation of playing minutes across games (Scanlan et al., 2015). Existing data have shown a significant decrease in high-intensity actions (Ben Abdelkrim et al., 2007; Reina et al., 2019), total distance and player load between Quarters 1 and 2 in professional basketball (García et al., 2020). This decrease in external load was also evident between Quarters 3 and 4 in semi-professional basketball (Scanlan et al., 2015) and between early periods and overtime, as evidenced by a reduction in player load and low- and medium-intensity accelerations (Scanlan et al., 2019). Consequently, the physical demands imposed on players appears to decrease with game progression in basketball. Given these load fluctuations between quarters, it is likely that differences between quarters may also be apparent when assessing MDS.

When assessing the physical demands encountered by players for the purpose of optimizing training prescription, previous research has also detailed the importance of assessing demands relative to playing positions (Svilar et al., 2018). Based on their anthropometric characteristics, playing area, and individual skills (Gryko et al., 2018), basketball players are commonly categorised as guard, forward, and centre positions. In this regard, differences in physical demands have been shown among playing positions during training (Svilar et al., 2018) and games (Salazar et al., 2020) in professional male basketball players. In addition, a recent study by Vazquez-Guerrero et al. (2020) showed that the MDS of game-play are position-dependent in elite U-18 basketball players. However, no such investigation has been conducted to determine whether differences in the MDS faced by different playing positions and across game quarters also appear at a professional level in basketball. As such, to ensure precise training prescription at the professional level, a separate investigation assessing the MDS of professional players across game quarters and concerning positional differences is warranted. Thus, the purpose of this study was to compare the MDS encountered by professional basketball players across game quarters and playing positions during official match-play.

Methods

An observational design was used to compare the MDS of basketball match-play across game quarters and playing positions. Local positioning system data were collected from 11 competitive league games during the 2018-19 season, completed on the same official basketball court in similar environmental conditions. Players who were injured during the game or did not play a minimum total time of 5 min were excluded from the analysis of that game (Vázquez-Guerrero et al., 2019), resulting in a total of 1809 individual observations.

The ten professional male basketball players (mean ± SD, age: 20.0 ± 1.5 yr; height: 200.9 ± 8.4 cm; and body mass: 93.6 ± 16.0 kg) that participated in this investigation belonged to a reserve squad of a Spanish Euroleague team and competed in LEB Oro (Spanish second division). All players were categorized into one of three playing positions: guards, forwards, and centres. Match-play was conducted according to official FIBA rules. Ethics committee approval was not required because players were routinely monitored during all training sessions and games in the course of the competitive season (Winter & Maughan, 2009). However, they agreed to participate by providing their written consent prior to the commencement of the research. Additionally, the league permits publication of these data, and the study fulfilled the provisions of the Declaration of Helsinki (Harriss & Atkinson, 2015).

The team played one game a week, held between Friday and Sunday, after a standard 45-min warm-up consisting of dynamic stretching, specific mobility exercises and individual basketball-specific skills such as passing, shooting, and dribbling. Within each structured microcycle, the team usually rested the day after a game and completed three to four strength sessions and four to five basketball-specific training sessions before the game.

During match-play, all players were continuously monitored using a local positioning system (WIMU PRO™, RealTrack Systems S.L., Almería, Spain), although data were only included when players were competing on the court (e.g., time as substitutes or rest time between quarters was not included). This ultra-wideband system includes six antennas, which were placed in the form of a rectangle for better signal emission and reception (Figure 1). With a sampling frequency for positioning data of 18 Hz, the local positioning system operates using triangulation between the antennas and the units (the six antennas send a signal to the units every 55.5 ms). The device then calculates the time required to receive the signal and derives the unit position (coordinates X and

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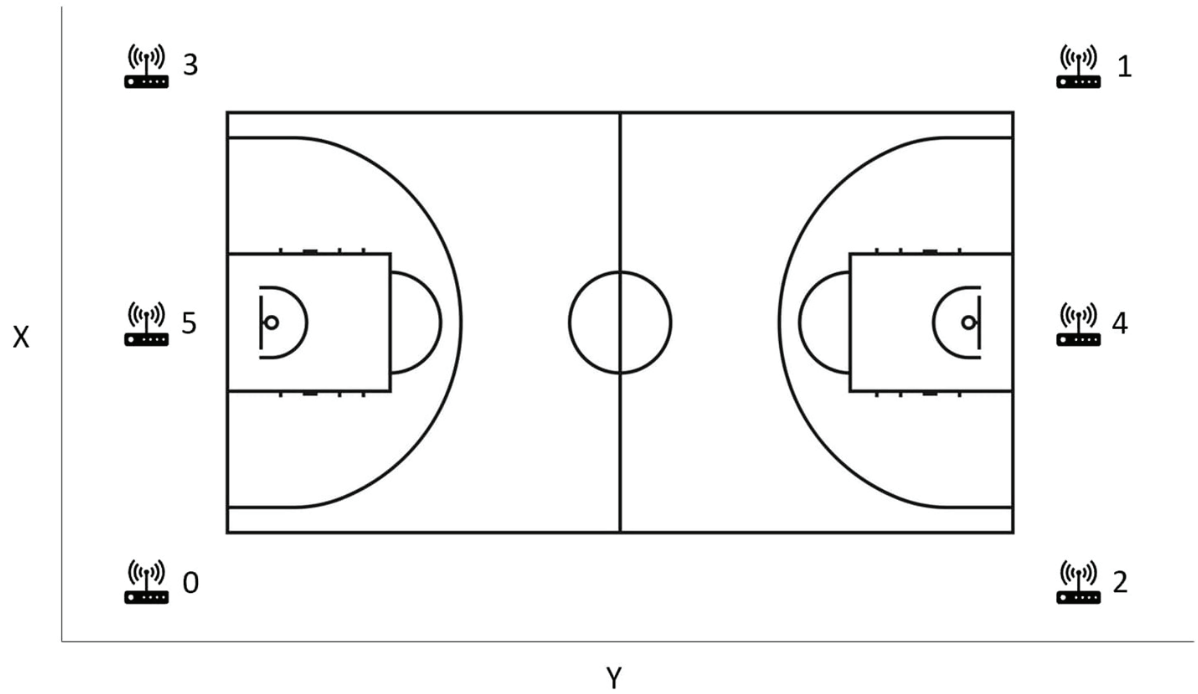

Figure 2. Ultra-wideband positioning system setup around the basketball court. X is court width, y is court length and z is height of the antenna. Numbers show the disposition of antennas in cm: 0 is x = 0, y = 0, z = 600; 1 is x = 2924, y = 5208, z = 600; 2 is x = 0, y = 5208, z = 600; 3 is x = 2928, y = 7, z = 600; 4 is x = 1469, y = 5207, z = 600; and 5 is x = 1456, y = 2, z = 600

Y) using one of the antennas as a reference.

Based on the manufacturer's recommendations, the tracking units were placed in a custom-made vest located in the centre of the player's upper back using an adjustable harness (IMAX, Lleida, Spain). Players wore the same inertial unit and vest for each game across the season to reduce any potential between-device variability. WIMU PRO™ has been shown to have good/acceptable accuracy and inter- and intra-unit reliability for ultra-wideband positioning (Bastida-Castillo et al., 2018, 2019). The system-specific SPRO™ software (version 958, RealTrack Systems, Almería, Spain) was used to download and analyse the data on the physical demands.

Similar to previous research (Vázquez-Guerrero et al., 2020; Whitehead et al., 2018), the following physical demand parameters were measured: 1) Total distance (m); 2) distance >18 $km{\cdot}h^{-1}$ (m); 3) distance >21 $km{\cdot}h^{-1}$ (m); 4) number of sprints >18 $km{\cdot}h^{-1}$; 5) number of sprints >21 $km{\cdot}h^{-1}$; 6) number of accelerations >2 $m{\cdot}s^{-2}$; 7) number of decelerations >2 $m{\cdot}s^{-2}$; 8) number of accelerations >3 $m{\cdot}s^{-2}$; and 9) number of decelerations >3 $m{\cdot}s^{-2}$. The distance was measured via positional differentiation (change in location with each signal), whereas acceleration and deceleration were calculated via double differentiation from the positional data recorded by the local positioning system (Malone et al., 2017). In line with Vázquez-Guerrero et al. (2020), the analysis of the MDS consisted of identifying the maximum values of the physical demand parameters of interest using a rolling average technique over five different periods (30, 60, 120, 180 and 300 s). The 30-s period was chosen because it represents the average duration of continuous playing before a stoppage is encountered in professional basketball, even though longer scenarios up to 120-s are uncommon but possible (Salazar & Castellano, 2020). In addition, 180- and 300-s periods were chosen as these durations reflect those often used by coaches when prescribing training drills (Vázquez-Guerrero et al., 2020).

All data are presented as mean ± standard deviation (SD). For each outcome measure, linear mixed models with Bonferroni post hoc tests were used to compare the MDS between game quarters for each positional group (guards, forwards, and centres). In the model, a game quarter was included as the fixed term (4 levels), and a participant was included as a random term to account for multiple data samples obtained for each participant (Peugh, 2010). Linear mixed models with Bonferroni post hoc tests were also used to compare the MDS between playing positions within each game quarter. In these analyses, a position was included as the fixed term (3 levels) and participant as a random term. Statistical significance was accepted where $P < 0.05$.

For all pairwise comparisons, Cohen's effect sizes with 95% Confidence Intervals were computed and interpreted as trivial: <0.2, small: 0.2-0.59, moderate: 0.6–1.19, large: 1.2–1.99, and very large: ≥2 (Hopkins, 2006). Statistical analyses and post hoc tests were conducted using the “lmerTest” and “emmeans” packages, respectively, on RStudio (Version 4.0.2), and effects sizes and confidence intervals were calculated using a customized Excel spreadsheet (Version 15, Microsoft Corporation, Redmond, USA).

Results

Descriptive statistics for the MDS within each quarter for each positional group are presented in Table 1. Results of the statistical analyses between game quarters in centres are presented in Table 2. Among centres, total distance was higher in Quarter 1 than Quarter 2 in the 120-s and 180-s periods and higher in Quarter 3 than Quarter 2 in the 180-s period ($P < 0.05$). In addition, distance>21 $km{\cdot}h^{-1}$ was higher during Quarter 1 compared to Quarter 2 in the 60-s and 180-s periods ($P < 0.05$).

Table 1. Most demanding scenarios across game quarters in professional basketball players

	Most demanding scenarios (Mean ± Standard Deviation)								
	Total distance (m)	Distance > 18 km·h⁻¹ (m)	Sprints > 18 km·h⁻¹ (count)	Accelerations > 2 m·s⁻² (count)	Decelerations > 2 m·s⁻² (count)	Distance > 21 km·h⁻¹ (m)	Sprints > 21 km·h⁻¹ (count)	Accelerations > 3 m·s⁻² (count)	Decelerations > 3 m·s⁻² (count)
Centres: Quarter 1									
30-s period	69.4 ± 7.2	15.9 ± 7.2	1.6 ± 0.5	6.5 ± 1.9	6.4 ± 2.0	11.5 ± 6.0	1.5 ± 0.5	3.0 ± 1.1	2.9 ± 1.0
60-s period	117.1 ± 14.9	17.4 ± 7.4	1.8 ± 0.7	9.0 ± 2.6	8.3 ± 2.7	12.9 ± 7.1	1.6 ± 0.5	3.8 ± 1.5	3.4 ± 1.4
120-s period	207.2 ± 23.7	23.0 ± 9.3	2.6 ± 1.4	12.9 ± 4.9	12.2 ± 3.2	14.8 ± 7.5	1.9 ± 0.8	5.0 ± 2.7	4.9 ± 2.5
180-s period	287.4 ± 31.2	28.3 ± 16.5	3.1 ± 1.8	16.5 ± 6.4	15.0 ± 4.2	16.5 ± 9.7	2.2 ± 1.1	6.1 ± 3.4	5.7 ± 3.2
300-s period	408.9 ± 65.3	37.6 ± 23.5	4.9 ± 3.0	21.1 ± 6.6	19.4 ± 4.8	18.3 ± 12.4	2.7 ± 1.5	8.6 ± 5.4	8.0 ± 5.2
Centres: Quarter 2									
30-s period	71.6 ± 11.7	14.7 ± 7.0	1.4 ± 0.7	6.0 ± 1.5	5.5 ± 1.5	8.3 ± 4.6	1.3 ± 0.6	3.1 ± 1.2	2.4 ± 1.0
60-s period	116.8 ± 20.2	16.4 ± 8.0	1.7 ± 0.7	8.3 ± 2.2	7.7 ± 2.9	9.4 ± 5.8	1.4 ± 0.7	3.8 ± 1.5	3.3 ± 1.4
120-s period	181.4 ± 23.4	18.0 ± 8.2	2.6 ± 1.0	11.9 ± 4.2	11.5 ± 5.1	9.5 ± 5.7	1.5 ± 0.7	4.8 ± 2.0	4.4 ± 2.0
180-s period	246.7 ± 27.6	19.9 ± 9.1	3.0 ± 1.3	15.3 ± 6.3	14.9 ± 7.7	10.4 ± 5.8	1.7 ± 1.0	5.2 ± 2.5	4.9 ± 2.6
300-s period	369.8 ± 54.0	22.0 ± 10.3	3.4 ± 1.9	20.2 ± 10.2	17.9 ± 10.8	10.6 ± 5.8	1.7 ± 1.0	7.0 ± 3.4	6.1 ± 3.6
Centres: Quarter 3									
30-s period	69.1 ± 6.4	14.5 ± 5.3	1.6 ± 0.5	6.2 ± 1.5	5.7 ± 2.2	9.7 ± 4.0	1.3 ± 0.5	2.6 ± 1.3	2.7 ± 1.2
60-s period	116.4 ± 9.0	16.7 ± 6.4	1.7 ± 0.8	8.3 ± 2.5	7.9 ± 3.2	10.8 ± 4.6	1.6 ± 0.5	3.4 ± 1.7	3.7 ± 1.7
120-s period	197.9 ± 20.9	19.3 ± 8.3	2.3 ± 1.0	13.5 ± 4.2	11.9 ± 4.7	13.6 ± 7.4	1.8 ± 0.7	5.1 ± 2.4	5.3 ± 2.2
180-s period	273.9 ± 23.0	22.2 ± 8.5	2.7 ± 1.0	16.4 ± 6.0	15.3 ± 7.0	14.7 ± 7.5	2.0 ± 0.7	5.4 ± 2.9	5.7 ± 2.6
300-s period	386.1 ± 47.9	27.4 ± 15.4	3.8 ± 1.8	21.5 ± 8.3	20.4 ± 9.7	17.9 ± 10.4	2.5 ± 1.2	7.3 ± 4.4	7.0 ± 4.1
Centres: Quarter 4									
30-s period	72.8 ± 7.0	13.9 ± 4.8	1.4 ± 0.4	6.2 ± 1.4	6.3 ± 1.9	7.6 ± 3.7	1.2 ± 0.4	3.0 ± 1.0	3.1 ± 0.9
60-s period	120.9 ± 16.6	16.6 ± 6.1	1.9 ± 0.7	8.4 ± 1.7	8.3 ± 1.9	7.6 ± 3.7	1.2 ± 0.4	3.7 ± 1.8	3.7 ± 1.3
120-s period	195.6 ± 26.8	17.9 ± 9.0	2.4 ± 1.5	11.5 ± 3.2	10.9 ± 2.6	8.8 ± 4.7	1.4 ± 0.8	5.1 ± 2.5	4.6 ± 2.3
180-s period	261.4 ± 25.0	22.6 ± 10.9	3.5 ± 1.7	13.9 ± 2.8	12.5 ± 1.7	9.0 ± 5.5	1.5 ± 1.0	5.5 ± 2.8	5.0 ± 2.2
300-s period	372.0 ± 47.8	24.2 ± 11.3	3.8 ± 1.9	18.3 ± 3.9	16.8 ± 3.4	10.9 ± 8.0	1.8 ± 1.3	6.9 ± 3.1	6.2 ± 2.4
Guards: Quarter 1									
30-s period	79.4 ± 8.8	14.0 ± 6.4	1.9 ± 0.9	7.0 ± 2.0	7.0 ± 2.0	7.1 ± 4.4	1.2 ± 0.4	3.7 ± 1.1	3.5 ± 1.4
60-s period	133.1 ± 24.1	15.7 ± 7.2	2.4 ± 1.1	10.0 ± 2.0	9.6 ± 1.9	7.3 ± 4.4	1.3 ± 0.4	4.8 ± 1.8	4.6 ± 1.6
120-s period	227.6 ± 42.2	18.4 ± 8.5	2.8 ± 1.3	15.4 ± 4.0	14.3 ± 3.4	8.1 ± 5.3	1.5 ± 0.7	6.8 ± 2.7	6.5 ± 2.8
180-s period	314.4 ± 56.6	21.0 ± 10.8	3.3 ± 1.7	20.7 ± 5.9	19.2 ± 5.4	9.1 ± 6.2	1.8 ± 0.9	8.3 ± 3.2	8.2 ± 3.7
300-s period	472.9 ± 68.3	24.7 ± 15.7	4.1 ± 2.1	28.0 ± 8.6	25.4 ± 7.6	10.2 ± 7.8	2.0 ± 1.2	11.1 ± 4.3	10.5 ± 5.7
Guards: Quarter 2									
30-s period	78.9 ± 8.9	12.9 ± 7.2	1.6 ± 0.8	6.8 ± 1.6	6.4 ± 1.5	8.0 ± 3.6	1.2 ± 0.5	3.6 ± 1.0	2.9 ± 0.9
60-s period	128.6 ± 13.8	14.4 ± 9.0	1.9 ± 0.9	9.3 ± 2.1	8.5 ± 1.9	8.4 ± 4.0	1.3 ± 0.7	4.4 ± 1.5	4.0 ± 1.4
120-s period	214.2 ± 22.4	17.7 ± 12.8	2.0 ± 1.2	13.1 ± 3.5	12.3 ± 3.4	9.0 ± 4.9	1.5 ± 0.8	6.2 ± 2.6	5.4 ± 2.2
180-s period	285.0 ± 34.6	19.6 ± 12.4	2.7 ± 1.5	16.9 ± 4.9	15.3 ± 4.5	9.3 ± 5.0	1.6 ± 0.8	7.2 ± 2.9	6.2 ± 2.4
300-s period	402.4 ± 67.9	24.5 ± 16.0	3.4 ± 2.0	22.8 ± 6.5	20.9 ± 6.3	10.5 ± 5.7	1.9 ± 0.9	9.4 ± 3.6	8.3 ± 3.4

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Table 1. Most demanding scenarios across game quarters in professional basketball players

	Most demanding scenarios (Mean ± Standard Deviation)								
	Total distance (m)	**Distance > 18 km·h⁻¹ (m)**	**Sprints > 18 km·h⁻¹ (count)**	**Accelerations > 2 m·s⁻² (count)**	**Decelerations > 2 m·s⁻² (count)**	**Distance > 21 km·h⁻¹ (m)**	**Sprints > 21 km·h⁻¹ (count)**	**Accelerations > 3 m·s⁻² (count)**	**Decelerations > 3 m·s⁻² (count)**
Guards: Quarter 3									
30-s period	75.7 ± 6.8	12.6 ± 4.8	1.7 ± 0.7	7.1 ± 2.1	6.8 ± 1.8	7.2 ± 3.8	1.1 ± 0.4	3.4 ± 1.2	3.1 ± 1.0
60-s period	129.7 ± 12.4	15.0 ± 6.4	2.1 ± 0.8	9.7 ± 1.9	9.2 ± 1.9	7.9 ± 4.7	1.3 ± 0.5	4.3 ± 1.7	4.2 ± 1.4
120-s period	215.2 ± 18.6	19.8 ± 12.7	2.4 ± 1.2	14.4 ± 3.0	13.4 ± 3.4	8.6 ± 5.2	1.5 ± 0.6	6.6 ± 3.8	6.3 ± 2.3
180-s period	294.8 ± 26.2	22.2 ± 10.6	3.2 ± 1.2	18.3 ± 3.9	16.8 ± 4.1	9.2 ± 5.6	1.6 ± 0.6	7.2 ± 2.8	7.2 ± 2.5
300-s period	432.5 ± 61.0	26.9 ± 14.2	3.8 ± 1.6	25.0 ± 6.8	22.5 ± 6.4	9.6 ± 6.1	1.7 ± 0.7	9.4 ± 4.0	9.7 ± 3.6
Guards: Quarter 4									
30-s period	76.9 ± 8.1	14.5 ± 5.5	1.8 ± 0.8	6.8 ± 1.8	6.6 ± 2.2	8.2 ± 3.7	1.1 ± 0.3	3.3 ± 1.1	3.1 ± 1.2
60-s period	128.0 ± 12.8	16.6 ± 7.8	2.0 ± 1.0	9.0 ± 1.8	8.7 ± 2.4	8.9 ± 5.2	1.2 ± 0.5	4.3 ± 1.8	4.0 ± 1.6
120-s period	216.5 ± 19.1	21.0 ± 12.6	2.3 ± 1.3	13.3 ± 3.5	13.1 ± 4.3	9.6 ± 5.5	1.3 ± 0.6	5.9 ± 2.9	6.0 ± 2.5
180-s period	291.0 ± 27.6	23.3 ± 10.4	3.2 ± 2.6	17.2 ± 4.5	16.4 ± 7.2	10.3 ± 6.6	1.5 ± 0.7	7.2 ± 3.4	6.9 ± 3.0
300-s period	418.4 ± 64.0	23.4 ± 14.6	3.4 ± 1.7	23.8 ± 7.0	22.6 ± 8.0	11.2 ± 7.9	1.7 ± 1.0	9.7 ± 5.6	8.9 ± 4.6
Forwards: Quarter 1									
30-s period	76.2 ± 9.4	14.5 ± 7.5	1.9 ± 0.8	6.0 ± 1.9	5.7 ± 1.8	8.9 ± 5.0	1.2 ± 0.5	2.6 ± 1.1	2.8 ± 1.0
60-s period	126.9 ± 19.4	16.3 ± 8.0	2.3 ± 1.0	8.0 ± 2.7	7.6 ± 2.4	9.5 ± 5.1	1.4 ± 0.7	3.3 ± 1.4	3.2 ± 1.4
120-s period	222.9 ± 25.7	19.9 ± 10.6	2.6 ± 1.6	13.0 ± 4.2	11.9 ± 4.6	10.4 ± 5.7	1.7 ± 0.7	4.8 ± 2.3	4.1 ± 2.0
180-s period	315.1 ± 36.4	25.0 ± 13.7	3.3 ± 1.9	17.2 ± 5.3	16.2 ± 6.4	11.1 ± 6.7	1.9 ± 1.1	5.9 ± 2.8	5.2 ± 2.7
300-s period	453.3 ± 74.7	26.0 ± 17.2	3.8 ± 2.5	22.6 ± 9.6	20.8 ± 8.7	11.6 ± 7.2	2.0 ± 1.2	7.6 ± 3.8	6.5 ± 3.4
Forwards: Quarter 2									
30-s period	80.1 ± 9.3	16.9 ± 9.2	1.9 ± 0.7	6.1 ± 1.5	5.5 ± 1.1	9.0 ± 6.3	1.4 ± 0.7	2.5 ± 1.1	2.4 ± 0.8
60-s period	127.7 ± 12.8	19.4 ± 9.5	2.2 ± 0.8	8.1 ± 2.2	7.6 ± 1.8	10.3 ± 6.6	1.5 ± 0.8	3.0 ± 1.3	2.8 ± 1.1
120-s period	208.8 ± 16.3	21.6 ± 10.8	2.5 ± 1.3	11.6 ± 3.6	10.6 ± 2.9	10.4 ± 6.9	1.7 ± 0.9	4.0 ± 2.1	3.9 ± 2.0
180-s period	279.7 ± 22.0	22.4 ± 14.0	2.7 ± 1.1	14.7 ± 4.4	13.5 ± 3.8	10.8 ± 7.0	1.8 ± 1.0	4.8 ± 2.5	4.4 ± 2.8
300-s period	401.7 ± 59.2	25.5 ± 12.8	3.5 ± 1.5	20.2 ± 7.1	18.1 ± 6.4	11.1 ± 7.7	1.9 ± 1.1	6.0 ± 3.6	5.3 ± 3.4
Forwards: Quarter 3									
30-s period	75.8 ± 6.1	14.2 ± 5.6	1.7 ± 0.6	6.3 ± 1.6	5.5 ± 1.7	8.4 ± 4.6	1.2 ± 0.4	2.8 ± 1.3	2.7 ± 1.3
60-s period	126.5 ± 9.3	15.8 ± 6.6	2.0 ± 0.8	8.4 ± 2.6	7.6 ± 2.3	9.1 ± 5.5	1.3 ± 0.5	3.5 ± 1.8	3.2 ± 2.0
120-s period	214.5 ± 18.0	18.4 ± 10.1	2.4 ± 1.4	12.2 ± 4.1	10.6 ± 3.3	10.5 ± 7.2	1.5 ± 0.7	4.9 ± 2.5	4.2 ± 2.6
180-s period	295.2 ± 28.0	23.8 ± 12.8	3.4 ± 1.5	15.6 ± 5.2	14.0 ± 4.4	11.4 ± 8.4	1.6 ± 0.8	5.8 ± 2.8	5.1 ± 3.4
300-s period	424.4 ± 59.8	25.5 ± 15.7	3.8 ± 1.9	22.5 ± 9.7	19.8 ± 7.6	11.8 ± 9.5	1.7 ± 1.2	8.0 ± 4.4	6.7 ± 4.8
Forwards: Quarter 4									
30-s period	75.6 ± 9.4	13.2 ± 5.7	1.6 ± 0.7	6.0 ± 1.4	5.3 ± 1.8	8.9 ± 4.6	1.2 ± 0.4	2.5 ± 1.2	2.1 ± 0.7
60-s period	124.6 ± 17.2	15.1 ± 7.9	2.1 ± 1.0	8.1 ± 1.9	7.1 ± 2.3	9.6 ± 5.6	1.4 ± 0.7	3.1 ± 1.5	2.5 ± 1.0
120-s period	210.2 ± 34.0	17.8 ± 10.2	2.3 ± 1.4	11.5 ± 3.9	9.6 ± 3.7	10.9 ± 6.5	1.7 ± 0.8	5.1 ± 3.1	3.7 ± 2.8
180-s period	276.6 ± 48.6	21.4 ± 12.1	3.2 ± 1.6	14.6 ± 5.2	12.8 ± 4.7	12.3 ± 7.9	1.9 ± 0.9	5.4 ± 3.4	3.8 ± 2.0
300-s period	405.8 ± 62.6	26.3 ± 15.1	3.9 ± 2.0	20.9 ± 8.1	18.3 ± 7.3	14.9 ± 11.2	2.1 ± 1.1	7.4 ± 4.6	5.0 ± 2.6

Table 2. Pairwise comparisons for the most demanding scenarios between game quarters in Centres

	Quarter comparisons: Centres (Effect Size±95% Confidence Intervals, *P*)								
	Total distance	**Distance > 18 km·h⁻¹**	**Sprints > 18 km·h⁻¹**	**Accelerations > 2 m·s⁻²**	**Decelerations > 2 m·s⁻²**	**Distance > 21 km·h⁻¹**	**Sprints > 21 km·h⁻¹**	**Accelerations > 3 m·s⁻²**	**Decelerations > 3 m·s⁻²**
30-s period									
Q1 vs Q2	0.22±0.63,1.0	0.17±0.65,1.0	0.33±0.65,1.0	0.28±0.63,1.0	0.51±0.64,0.92	0.65±0.71,0.27[M]	0.40±0.70,1.0	0.05±0.67,1.0	0.50±0.68,1.0
Q1 vs Q3	0.05±0.64,1.0	0.19±0.66,1.0	0.0±0.65,1.0	0.17±0.65,1.0	0.33±0.64,1.0	0.41±0.72,1.0	0.28±0.71,1.0	0.36±0.68,1.0	0.14±0.69,1.0
Q1 vs Q4	0.48±0.67,1.0	0.33±0.68,1.0	0.44±0.66,1.0	0.14±0.66,1.0	0.02±0.68,1.0	0.83±0.74,0.12[M]	0.54±0.73,1.0	0.0±0.71,1.0	0.20±0.70, 1.0
Q2 vs Q3	0.26±0.64,1.0	0.0±0.66,1.0	0.33±0.66,1.0	0.11±0.64,1.0	0.11±0.64,1.0	0.31±0.7,1.0	0.15±0.70,1.0	0.40±0.68,1.0	0.31±0.70,1.0
Q2 vs Q4	0.12±0.68,1.0	0.14±0.68,1.0	0.0±0.65,1.0	0.14±0.67,1.0	0.51±0.68,1.0	0.17±0.72,1.0	0.08±0.71,1.0	0.05±0.71,1.0	0.71±0.72,0.44[M]
Q3 vs Q4	0.56±0.68,1.0	0.16±0.69,1.0	0.44±0.65,1.0	0.02±0.68,1.0	0.32±0.68,1.0	0.53±0.73,1.0	0.26±0.72,1.0	0.37±0.71,1.0	0.31±0.73,1.0
60-s period									
Q1 vs Q2	0.02±0.64,1.0	0.13±0.65,1.0	0.57±0.65,1.0	0.28±0.64,1.0	0.21±0.63,1.0	0.54±0.70,0.49	0.36±0.70,1.0	0.0±0.64,1.0	0.10±0.65,1.0
Q1 vs Q3	0.05±0.65,1.0	0.11±0.66,1.0	0.33±0.65,1.0	0.28±0.64,1.0	0.13±0.64,1.0	0.36±0.71,1.0	0.0±0.72,1.0	0.25±0.64,1.0	0.15±0.66,1.0
Q1 vs Q4	0.24±0.68,1.0	0.13±0.68,1.0	0.57±0.65,1.0	0.27±0.67,1.0	0.03±0.68,1.0	0.93±0.73,0.07[M]	0.82±0.73,0.40[M]	0.07±0.67,1.0	0.23±0.68,1.0
Q2 vs Q3	0.02±0.65,1.0	0.03±0.66,1.0	0.0±0.65,1.0	0.02±0.64,1.0	0.07±0.64,1.0	0.26±0.70,1.0	0.36±0.70,1.0	0.25±0.64,1.0	0.24±0.66,1.0
Q2 vs Q4	0.22±0.68,1.0	0.02±0.69,1.0	0.29±0.69,1.0	0.04±0.68,1.0	0.26±0.67,1.0	0.37±0.71,1.0	0.28±0.71,1.0	0.07±0.67,1.0	0.34±0.68,1.0
Q3 vs Q4	0.35±0.68,1.0	0.02±0.69,1.0	0.27±0.66,1.0	0.05±0.69,1.0	0.16±0.69,1.0	0.75±0.74,0.76[M]	0.82±0.74,0.40[M]	0.17±0.68,1.0	0.05±0.70,1.0
120-s period									
Q1 vs Q2	1.1±0.67,**0.011**[M]	0.58±0.72,.72	0.0±0.69,1.0	0.22±0.70,1.0	0.17±0.70,1.0	0.81±0.73,0.19[M]	0.56±0.73,0.78	0.07±0.69,1.0	0.23±0.69,1.0
Q1 vs Q3	0.42±0.67,1.0	0.42±0.72,1.0	0.20±0.70,1.0	0.12±0.72,1.0	0.08±0.73,1.0	0.15±0.76,1.0	0.18±0.75,1.0	0.02±0.71,1.0	0.19±0.72,1.0
Q1 vs Q4	0.46±0.69,1.0	0.56±0.74,.72	0.09±0.72,1.0	0.33±0.75,1.0	0.44±0.75,1.0	0.97±0.76,0.11[M]	0.64±0.76,0.52[M]	0.05±0.71,1.0	0.11±0.72,1.0
Q2 vs Q3	0.74±0.66,0.25[M]	0.16±0.71,1.0	0.24±0.70,1.0	0.36±0.69,1.0	0.08±0.69,1.0	0.63±0.72,0.49[M]	0.40±0.72,1.0	0.10±0.67,1.0	0.47±0.69,1.0
Q2 vs Q4	0.57±0.68,0.52	0.02±0.72,1.0	0.11±0.71,1.0	0.10±0.72,1.0	0.13±0.72,1.0	0.13±0.72,1.0	0.09±0.72,1.0	0.13±0.69,1.0	0.12±0.69,1.0
Q3 vs Q4	1.0±0.7,1.0	0.16±0.72,1.0	0.09±0.73,1.0	0.51±0.74,1.0	0.25±0.74,1.0	0.78±0.75,0.3[M]	0.49±0.74,1.0	0.03±0.70,1.0	0.33±0.71,1.0
180-s period									
Q1 vs Q2	1.39±0.69,<**0.001**[L]	0.63±0.69,.30[M]	0.08±0.69,1.0	0.19±0.70,1.0	0.02±0.72,1.0	0.77±0.75,0.19[M]	0.49±0.74,1.0	0.32±0.69,1.0	0.25±0.70,1.0
Q1 vs Q3	0.49±0.68,0.94	0.39±0.73,.98	0.28±0.71,1.0	0.02±0.74,1.0	0.05±0.74,1.0	0.21±0.78,1.0	0.24±0.78,1.0	0.22±0.72,1.0	0.01±0.74,1.0
Q1 vs Q4	0.91±0.72,0.06[M]	0.39±0.73,1.0	0.24±0.74,1.0	0.53±0.75,1.0	0.75±0.76,1.0[M]	0.95±0.78,0.07[M]	0.67±0.77,0.42[M]	0.21±0.74,1.0	0.24±0.74,1.0
Q2 vs Q3	1.06±0.69,**0.026**[M]	0.26±0.73,1.0	0.25±0.71,1.0	0.17±0.71,1.0	0.06±0.72,1.0	0.64±0.76,0.82[M]	0.31±.75,1.0	0.09±0.71,1.0	0.29±0.73,1.0
Q2 vs Q4	0.55±0.69,0.77	0.27±0.74,1.0	0.36±0.75,1.0	0.28±0.72,1.0	0.40±0.73,1.0	0.25±0.74,1.0	0.20±0.74,1.0	0.11±0.72,1.0	0.03±0.73,1.0
Q3 vs Q4	0.52±0.725,1.0	0.05±0.76,1.0	0.59±0.79,.92	0.53±0.75,1.0	0.53±0.75,1.0	0.87±0.79,0.34[M]	0.53±0.78,1.0	0.01±0.76,1.0	0.29±0.76,1.0
300-s period									
Q1 vs Q2	0.66±0.68,.27[M]	0.85±0.79,.36[M]	0.57±0.78,1.0	0.10±0.78,1.0	0.18±0.78,1.0	0.80±0.79,.27[M]	0.78±0.79,.36[M]	0.37±0.72,1.0	0.44±0.74,1.0
Q1 vs Q3	0.39±0.73,1.0	0.07±0.77,1.0	0.61±0.78,1.0[M]	0.06±0.80,1.0	0.13±0.81,1.0	0.04±0.82,1.0	0.15±0.81,1.0	0.27±0.78,1.0	0.21±0.81,1.0
Q1 vs Q4	0.64±0.72,.42[M]	0.72±0.78,.80[M]	0.44±0.78,1.0	0.52±0.79,1.0	0.62±0.8,1.0[M]	0.71±0.82,.33[M]	0.58±0.78,.67	0.40±0.75,1.0	0.45±0.75,1.0
Q2 vs Q3	0.32±0.73,1.0	0.55±0.82,1.0	0.05±0.8,1.0	0.14±0.79,1.0	0.24±0.8,1.0	0.88±0.81,0.39[M]	0.71±0.85,.89[M]	0.07±0.78,1.0	0.25±0.80,1.0
Q2 vs Q4	0.04±0.71,1.0	0.20±0.81,1.0	0.18±0.81,1.0	0.25±0.78,1.0	0.13±0.78,1.0	0.05±0.76,1.0	0.13±0.77,1.0	0.05±0.74,1.0	0.03±0.75,1.0
Q3 vs Q4	0.30±0.75,1.0	0.46±0.78,1.0	0.23±0.81,1.0	0.50±0.79,1.0	0.49±0.79,1.0	0.76±0.80,.46[M]	0.47±0.79,1.0	0.11±0.80,1.0	0.26±0.82,1.0

Note: Bolded P value indicates significant ($P < 0.05$) difference, [M] indicates moderate (0.6 – 1.19) effect size, [L] indicates large (1.2 – 1.99) effect size, Q1 = Quarter 1, Q2 = Quarter 2, Q3 = Quarter 3, Q4 = Quarter 4.

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Table 3. Pairwise comparisons for the most demanding scenarios between game quarters in Guards

	Quarter comparisons: Guards (Effect Size±95% Confidence Intervals, *P*)								
	Total distance	**Distance > 18 km·h⁻¹**	**Sprints > 18 km·h⁻¹**	**Accelerations > 2 m·s⁻²**	**Decelerations > 2 m·s⁻²**	**Distance > 21 km·h⁻¹**	**Sprints > 21 km·h⁻¹**	**Accelerations > 3 m·s⁻²**	**Decelerations > 3 m·s⁻²**
30-s period									
Q1 vs Q2	0.06±0.43,1.0	0.16±0.43,1.0	0.34±0.44,0.72	0.11±0.43,1.0	0.33±0.43,1.0	0.22±0.50,1.0	0.12±0.49,1.0	0.10±0.45,1.0	0.51±0.46,0.15
Q1 vs Q3	0.47±0.45,.30	0.24±0.45,1.0	0.32±0.45,1.0	0.06±0.45,1.0	0.07±0.44,1.0	0.02±0.51,1.0	0.03±0.50,1.0	0.24±0.47,1.0	0.32±0.47,0.87
Q1 vs Q4	0.29±0.45,1.0	0.09±0.45,1.0	0.14±0.45,1.0	0.06±0.45,1.0	0.19±0.45,1.0	0.25±0.50,1.0	0.25±0.50,1.0	0.30±0.47,1.0	0.28±0.47,1.0
Q2 vs Q3	0.40±0.43,0.50	0.04±0.44,1.0	0.04±0.44,1.0	0.18±0.43,1.0	0.27±0.43,1.0	0.22±0.51,1.0	0.14±0.51,1.0	0.15±0.46,1.0	0.20±0.45,1.0
Q2 vs Q4	0.23±0.43,1.0	0.25±0.45,1.0	0.20±0.44,1.0	0.05±0.44,1.0	0.10±0.43,1.0	0.04±0.51,1.0	0.34±0.50,1.0	0.21±0.46,1.0	0.21±0.46,1.0
Q3 vs Q4	0.17±0.45,1.0	0.36±0.47,1.0	0.17±0.52,1.0	0.12±0.45,1.0	0.13±0.46,1.0	0.25±0.52,1.0	0.22±0.52,1.0	0.05±0.48,1.0	0.03±0.47,1.0
60-s period									
Q1 vs Q2	0.23±0.43,1.0	0.16±0.44,1.0	0.59±0.44,**0.037**	0.38±0.44,0.44	0.55±0.44,0.13	0.24±0.50,1.0	0.09±0.50,1.0	0.24±0.43,1.0	0.39±0.43,0.49
Q1 vs Q3	0.17±0.45,1.0	0.11±0.45,1.0	0.40±0.45,0.58	0.18±0.45,1.0	0.23±0.45,1.0	0.11±0.51,1.0	0.08±0.51,1.0	0.29±0.45,1.0	0.26±0.45,1.0
Q1 vs Q4	0.26±0.45,1.0	0.12±0.46,1.0	0.40±0.46,0.36	0.55±0.45,0.14	0.41±0.46,0.36	0.34±0.50,1.0	0.09±0.50,1.0	0.31±0.45,0.99	0.65±0.47,0.50[M]
Q2 vs Q3	0.08±0.44,1.0	0.08±0.44,1.0	0.26±0.44,1.0	0.22±0.43,1.0	0.33±0.43,1.0	0.12±0.51,1.0	0.03±0.51,1.0	0.07±0.43,1.0	0.14±0.44,1.0
Q2 vs Q4	0.05±0.43,1.0	0.26±0.45,1.0	0.18±0.44,1.0	0.13±0.44,1.0	0.07±0.44,1.0	0.12±0.51,1.0	0.16±0.51,1.0	0.10±0.43,1.0	0.99±0.46,1.0[M]
Q3 vs Q4	0.14±0.45,1.0	0.22±0.46,1.0	0.06±0.45,1.0	0.37±0.46,0.82	0.22±0.45,1.0	0.22±0.52,1.0	0.17±0.52,1.0	0.03±0.45,1.0	0.87±0.47,1.0[M]
120-s period									
Q1 vs Q2	0.41±0.43,0.16	0.06±0.49,1.0	0.64±0.47,.05[M]	0.61±0.49,0.07[M]	0.59±0.49,0.18	0.18±0.52,1.0	0.05±0.53,1.0	0.24±0.46,1.0	0.46±0.46,0.29
Q1 vs Q3	0.38±0.45,0.31	0.06±0.51,1.0	0.28±0.49,1.0	0.28±0.51,1.0	0.26±0.51,1.0	0.10±0.52,1.0	0.12±0.52,1.0	0.08±0.47,1.0	0.06±0.47,1.0
Q1 vs Q4	0.34±0.45,0.49	0.10±0.52,1.0	0.36±0.49,.79	0.55±0.52,0.17	0.31±0.51,1.0	0.26±0.52,1.0	0.30±0.51,1.0	0.33±0.48,1.0	0.19±0.48,1.0
Q2 vs Q3	0.05±0.44,1.0	0.02±0.50,1.0	0.37±0.48,.88	0.39±0.49,0.93	0.33±0.49,1.0	0.08±0.52,1.0	0.06±0.52,1.0	0.12±0.44,1.0	0.43±0.45,0.47
Q2 vs Q4	0.11±0.44,1.0	0.14±0.50,1.0	0.26±0.48,1.0	0.05±0.51,1.0	0.21±0.50,1.0	0.10±0.52,1.0	0.23±0.51,1.0	0.10±0.46,1.0	0.26±0.45,1.0
Q3 vs Q4	0.07±0.46,1.0	0.16±0.52,1.0	0.09±0.49,1.0	0.33±0.53,1.0	0.08±0.52,1.0	0.17±0.52,1.0	0.20±0.52,1.0	0.19±0.47,1.0	0.15±0.47,1.0
180-s period									
Q1 vs Q2	0.64±0.44,**.004**[M]	0.12±0.48,1.0	0.38±0.47,.52	0.71±0.48,**.009**[M]	0.78±0.48,**.008**[M]	0.05±0.53,1.0	0.27±0.53,1.0	0.36±0.46,0.76	0.65±0.46,**0.024**[M]
Q1 vs Q3	0.44±0.45,.17	0.11±0.50,1.0	0.06±0.49,1.0	0.50±0.50,.26	0.49±0.49,.35	0.03±0.53,1.0	0.25±0.53,1.0	0.37±0.47,0.84	0.30±0.47,1.0
Q1 vs Q4	0.52±0.46,.06	0.19±0.50,1.0	0.28±0.49,1.0	0.82±0.51,**.03**[M]	0.51±0.50,.17	0.20±0.52,1.0	0.40±0.52,0.73	0.32±0.48,0.97	0.37±0.48,0.48
Q2 vs Q3	0.32±0.43,1.0	0.22±0.48,1.0	0.39±0.48,.86	0.30±0.48,1.0	0.35±0.48,1.0	0.02±0.54,1.0	0.04±0.54,1.0	0.0±0.45,1.0	0.43±0.45,0.75
Q2 vs Q4	0.19±0.44,1.0	0.28±0.49,1.0	0.10±0.66,1.0	0.10±0.48,1.0	0.22±0.48,1.0	0.17±0.52,1.0	0.13±0.53,1.0	0.01±0.46,1.0	0.27±0.46,1.0
Q3 vs Q4	0.14±0.46,1.0	0.10±0.50,1.0	0.28±0.50,1.0	0.43±0.50,1.0	0.09±0.50,1.0	0.18±0.53,1.0	0.19±0.52,1.0	0.01±0.48,1.0	0.12±0.47,1.0
300-s period									
Q1 vs Q2	1.03±0.47,<**0.001**[M]	0.01±0.51,1.0	0.34±0.51,.98	0.66±0.51,**.020**[M]	0.70±0.51,**.049**[M]	0.03±0.54,1.0	0.18±0.53,1.0	0.15±1.08,0.65	0.47±0.47,0.22
Q1 vs Q3	0.62±0.47,0.06[M]	0.15±0.52,1.0	0.19±0.52,1.0	0.39±0.52,.76	0.41±0.52,.78	0.09±0.53,1.0	0.34±0.53,1.0	0.41±0.48,0.69	0.17±0.48,1.0
Q1 vs Q4	0.82±0.47,**0.003**[M]	0.11±0.53,1.0	0.05±0.52,.82	0.54±0.53,.22	0.36±0.53,.89	0.21±0.55,1.0	0.32±0.52,1.0	0.27±0.48,1.0	0.30±0.49,0.89
Q2 vs Q3	0.46±0.45,0.28	0.15±0.52,1.0	0.19±0.5,1.0	0.31±0.52,.96	0.32±0.52,1.0	0.14±0.54,1.0	0.19±0.54,1.0	0.0±1.08,1.0	0.40±0.46,1.0
Q2 vs Q4	0.24±0.45,1.0	0.09±0.53,1.0	0.0±0.51,1.0	0.14±0.53,1.0	0.30±0.53,1.0	0.31±0.56,1.0	0.18±0.53,1.0	0.03±1.08,1.0	0.16±0.46,1.0
Q3 vs Q4	0.23±0.46,1.0	0.24±0.64,1.0	0.08±0.53,1.0	0.17±0.53,1.0	0.01±0.53,1.0	0.14±0.56,1.0	0.02±0.53,1.0	0.08±0.48,1.0	0.19±0.48,1.0

Note: Bolded P value indicates significant ($P < 0.05$) difference, M indicates moderate (0.6 – 1.19) effect size, L indicates large (1.2 – 1.99) effect size, Q1 = Quarter 1, Q2 = Quarter 2, Q3 = Quarter 3, Q4 = Quarter 4.

Table 4. Pairwise comparisons for the most demanding scenarios between game quarters in Forwards

	Quarter comparisons: Forwards (Effect Size±95% Confidence Intervals, *P*)								
	Total distance	**Distance > 18 km·h⁻¹**	**Sprints > 18 km·h⁻¹**	**Accelerations > 2 m·s⁻²**	**Decelerations > 2 m·s⁻²**	**Distance > 21 km·h⁻¹**	**Sprints > 21 km·h⁻¹**	**Accelerations > 3 m·s⁻²**	**Decelerations > 3 m·s⁻²**
30-s period									
Q1 vs Q2	0.42±0.49,0.47	0.29±0.51,1.0	0.04±0.50,1.0	0.03±0.50,1.0	0.19±0.50,1.0	0.01±0.57,1.0	0.18±0.57,1.0	0.03±0.52,1.0	0.46±0.53,0.77
Q1 vs Q3	0.05±0.49,1.0	0.04±0.51,1.0	0.26±0.50,1.0	0.14±0.49,1.0	0.15±0.50,1.0	0.12±0.57,1.0	0.20±0.57,1.0	0.18±0.52,1.0	0.04±0.53,1.0
Q1 vs Q4	0.06±0.50,1.0	0.19±0.51,1.0	0.38±0.51,0.71	0.02±0.50,1.0	0.23±0.50,1.0	0.02±0.59,1.0	0.13±0.59,1.0	0.03±0.52,1.0	0.83±0.55,0.07[M]
Q2 vs Q3	0.55±0.49,0.31	0.36±0.50,.78	0.24±0.50,1.0	0.12±0.49,1.0	0.01±0.50,1.0	0.12±0.54,1.0	0.36±0.53,1.0	0.22±0.52,1.0	0.32±0.52,0.99
Q2 vs Q4	0.48±0.50,0.27	0.48±0.50,.27	0.38±0.50,0.89	0.02±0.50,1.0	0.09±0.50,1.0	0.03±0.56,1.0	0.30±0.55,1.0	0.0±0.52,1.0	0.37±0.53,1.0
Q3 vs Q4	0.02±0.50,1.0	0.17±0.50,1.0	0.16±0.50,1.0	0.15±0.49,1.0	0.09±0.49,1.0	0.11±0.57,1.0	0.08±0.57,1.0	0.20±0.52,1.0	0.60±0.53,0.09[M]
60-s period									
Q1 vs Q2	0.05±0.5,1.0	0.36±0.52,.78	0.05±0.51,1.0	0.01±0.50,1.0	0.03±0.50,1.0	0.14±0.56,1.0	0.14±0.57,1.0	0.13±0.50,1.0	0.31±0.51,1.0
Q1 vs Q3	0.03±0.44,1.0	0.07±0.51,1.0	0.27±0.51,1.0	0.16±0.49,1.0	0.01±0.49,1.0	0.07±0.58,1.0	0.27±0.57,1.0	0.18±0.50,1.0	0.01±0.50,1.0
Q1 vs Q4	0.13±0.49,1.0	0.15±0.51,1.0	0.21±0.51,1.0	0.01±0.50,1.0	0.20±0.50,1.0	0.03±0.59,1.0	0.10±0.60,1.0	0.03±0.50,1.0	0.57±0.51,0.42
Q2 vs Q3	0.11±0.49,1.0	0.45±0.50,.46	0.25±0.5,1.0	0.16±0.49,1.0	0.04±0.50,1.0	0.20±0.53,1.0	0.42±0.53,0.90	0.29±0.50,1.0	0.25±0.50,1.0
Q2 vs Q4	0.21±0.49,1.0	0.50±0.50,.22	0.18±0.50,1.0	0.0±0.50,1.0	0.27±0.49,1.0	0.11±0.56,1.0	0.24±0.56,1.0	0.09±0.50,1.0	0.27±0.50,1.0
Q3 vs Q4	0.14±0.49,1.0	0.10±0.50,1.0	0.04±0.51,1.0	0.17±0.49,1.0	0.20±0.49,1.0	0.09±0.57,1.0	0.16±0.57,1.0	0.20±0.49,1.0	0.44±0.49,0.35
120-s period									
Q1 vs Q2	0.66±0.5,0.16[M]	0.16±0.65,1.0	0.08±0.52,1.0	0.36±0.55,1.0	0.34±0.55,1.0	0.01±0.60,1.0	0.0±0.60,1.0	0.39±0.53,1.0	0.15±0.52,1.0
Q1 vs Q3	0.38±0.50,1.0	0.14±0.56,1.0	0.14±0.53,1.0	0.18±0.56,1.0	0.32±0.56,1.0	0.01±0.60,1.0	0.19±0.60,1.0	0.02±0.53,1.0	0.01±0.53,1.0
Q1 vs Q4	0.42±0.50,0.27	0.20±0.56,1.0	0.25±0.53,1.0	0.38±0.56,1.0	0.54±0.56,0.21	0.08±0.61,1.0	0.0±0.61,1.0	0.11±0.51,1.0	0.18±0.52,1.0
Q2 vs Q3	0.33±0.50,1.0	0.31±0.65,1.0	0.07±0.52,1.0	0.16±0.55,1.0	0.01±0.55,1.0	0.02±0.56,1.0	0.17±0.55,1.0	0.39±0.53,1.0	0.14±0.52,1.0
Q2 vs Q4	0.05±0.50,1.0	0.36±0.6,1.0	0.19±0.52,1.0	0.04±0.55,1.0	0.29±0.54,1.0	0.08±0.57,1.0	0.0±0.57,1.0	0.43±0.51,0.54	0.06±0.51,1.0
Q3 vs Q4	0.16±0.50,1.0	0.06±0.55,1.0	0.12±0.53,1.0	0.19±0.55,1.0	0.28±0.55,1.0	0.06±0.58,1.0	0.19±0.57,1.0	0.09±0.51,1.0	0.17±0.51,1.0
180-s period									
Q1 vs Q2	1.17±0.54,**0.001**[M]	0.19±0.66,1.0	0.39±0.53,.96	0.53±0.55,0.41	0.42±0.84,0.27	0.04±0.60,1.0	0.13±0.59,1.0	0.42±0.54,0.91	0.26±0.53,1.0
Q1 vs Q3	0.61±0.51,0.18[M]	0.10±0.54,1.0	0.03±0.53,1.0	0.32±0.55,1.0	0.40±0.54,0.66	0.04±0.61,1.0	0.32±0.60,1.0	0.03±0.54,1.0	0.0±0.54,1.0
Q1 vs Q4	0.89±0.52,<**0.001**[M]	0.29±0.55,1.0	0.07±0.54,1.0	0.50±0.54,0.39	0.61±0.55,0.08[M]	0.16±0.63,1.0	0.04±0.63,1.0	0.17±0.53,1.0	0.56±0.54,0.47
Q2 vs Q3	0.61±0.51,0.53[M]	0.10±0.66,1.0	0.49±0.54,.73	0.19±0.52,1.0	0.28±0.83,1.0	0.08±0.56,1.0	0.20±0.47,1.0	0.39±0.52,1.0	0.26±0.52,1.0
Q2 vs Q4	0.08±0.50,1.0	0.08±0.65,1.0	0.34±0.54,1.0	0.01±0.52,1.0	0.17±0.83,1.0	0.20±0.58,1.0	0.10±0.58,1.0	0.20±0.53,1.0	0.25±0.53,1.0
Q3 vs Q4	0.47±0.50,0.24	0.19±0.53,1.0	0.11±0.53,1.0	0.18±0.52,1.0	0.27±0.52,1.0	0.10±0.59,1.0	0.32±0.59,1.0	0.14±0.52,1.0	0.55±0.52,0.46
300-s period									
Q1 vs Q2	0.78±0.53,**0.021**[M]	0.03±0.60,1.0	0.15±0.59,1.0	0.29±0.59,1.0	0.36±0.60,1.0	0.03±0.63,1.0	0.10±0.62,1.0	0.42±0.56,1.0	0.33±0.56,1.0
Q1 vs Q3	0.43±0.53,0.57	0.03±0.60,1.0	0.02±0.60,1.0	0.0±0.61,1.0	0.13±0.60,1.0	0.06±0.62,1.0	0.22±0.62,1.0	0.09±0.56,1.0	0.06±0.56,1.0
Q1 vs Q4	0.70±0.53,**0.042**[M]	0.02±0.60,1.0	0.06±0.60,1.0	0.19±0.60,1.0	0.31±0.60,1.0	0.36±0.65,1.0	0.09±0.64,1.0	0.06±0.55,1.0	0.48±0.55,1.0
Q2 vs Q3	0.38±0.50,1.0	0.0±0.56,1.0	0.16±0.56,1.0	0.28±0.55,1.0	0.24±0.56,1.0	0.09±0.57,1.0	0.20±0.59,1.0	0.49±0.53,0.50	0.34±0.53,0.98
Q2 vs Q4	0.07±0.5,1.0	0.06±0.56,1.0	0.25±0.57,1.0	0.09±0.56,1.0	0.04±0.56,1.0	0.40±0.59,1.0	0.12±0.57,1.0	0.32±0.54,1.0	0.09±0.54,1.0
Q3 vs Q4	0.30±0.51,1.0	0.05±0.57,1.0	0.09±0.57,1.0	0.18±0.56,1.0	0.19±0.57,1.0	0.29±0.60,1.0	0.31±0.60,1.0	0.14±0.53,1.0	0.44±0.53,0.55

Note: Bolded P value indicates significant ($P < 0.05$) difference, [M] indicates moderate (0.6 – 1.19) effect size, [L] indicates large (1.2 – 1.99) effect size, Q1 = Quarter 1, Q2 = Quarter 2, Q3 = Quarter 3, Q4 = Quarter 4.

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Table 5. Pairwise comparisons for the most demanding scenarios between playing positions within each game quarter

	Total distance	Distance > 18 km·h^{-1}	Sprints > 18 km·h^{-1}	Accelerations > 2 m·s^{-2}	Decelerations > 2 m·s^{-2}	Distance > 21 km·h^{-1}	Sprints > 21 km·h^{-1}	Accelerations > 3 m·s^{-2}	Decelerations > 3 m·s^{-2}
Quarter 1 (Effect Size±95% Confidence Intervals, *P*)									
30-s period									
C vs G	1.17±0.54,<**.001**^{M}	0.30±0.56,.97	0.41±0.67,1.0	0.25±0.54,1.0	0.30±0.55,0.81	0.95±0.62,**0.011**^{M}	0.77±0.62,0.09^{M}	0.58±0.58,0.15	0.50±0.58,0.209
C vs F	0.78±0.60,**.028**^{M}	0.20±0.59,1.0	0.45±0.67,1.0	0.24±0.57,1.0	0.33±0.57,0.82	0.52±0.67,0.281	0.43±0.66,0.43	0.39±0.60,0.65	0.11±0.61,1.0
G vs F	0.36±0.42,.38	0.08±0.48,1.0	0.04±0.48,1.0	0.49±0.47,0.14	0.64±0.47,**0.03**^{M}	0.39±0.55,0.58	0.21±0.54,1.0	0.97±0.51,**0.001**^{M}	0.61±0.52,**0.046**^{M}
60-s period									
C vs G	0.74±0.56,**0.022**^{M}	0.23±0.56,1.0	0.65±0.68,0.76^{M}	0.47±0.55,0.39	0.61±0.56,0.12^{M}	1.03±0.63,**0.004**^{M}	0.76±0.61,0.16^{M}	0.59±0.55,0.09	0.77±0.56,**0.017**^{M}
C vs F	0.55±0.57,0.33	0.15±0.59,1.0	0.58±0.68,1.0	0.37±0.56,0.51	0.27±0.57,0.89	0.57±0.66,0.18	0.26±0.66,1.0	0.41±0.57,0.62	0.18±0.58,1.0
G vs F	0.28±0.47,0.66	0.07±0.48,1.0	0.16±0.48,1.0	0.86±0.48,**0.003**^{M}	0.95±0.49,**0.001**^{M}	0.45±0.55,0.47	0.31±0.55,0.79	0.98±0.49,<**.001**^{M}	0.94±0.5,**.001**^{M}
120-s period									
C vs G	0.54±0.58,.13	0.53±0.63,.40	0.15±0.60,1.0	0.57±0.63,.24	0.62±0.64,.30^{M}	1.1±0.68,**.005**^{M}	0.51±0.66,.39	0.68±0.61,.08^{M}	0.60±0.61,.11^{M}
C vs F	0.63±0.59,.39^{M}	0.31±0.66,.96	0.04±0.62,1.0	0.02±0.65,1.0	0.08±0.66,1.0	0.67±0.71,.14^{M}	0.32±0.7,1.0	0.08±0.63,1.0	0.33±0.63,1.0
G vs F	0.13±0.48,1.0	0.16±0.54,1.0	0.09±0.51,1.0	0.58±0.54,.14	0.61±0.54,.07^{M}	0.42±0.58,.59	0.19±0.58,1.0	0.80±0.52,**.01**^{M}	0.96±0.52,**.001**^{M}
180-s period									
C vs G	0.54±0.57,.14	0.56±0.60,.24	0.09±0.60,1.0	0.70±0.66,.08^{M}	0.82±0.67,.07^{M}	0.99±0.67,**.010**^{M}	0.46±0.66,.59	0.66±0.65,.09^{M}	0.70±0.64,.05^{M}
C vs F	0.80±0.61,.16^{M}	0.22±0.63,1.0	0.10±0.62,1.0	0.12±0.66,1.0	0.21±0.67,1.0	0.67±0.71,.13^{M}	0.31±0.70,1.0	0.08±0.65,1.0	0.18±0.63,1.0
G vs F	0.01±0.49,1.0	0.33±0.54,.79	0.02±0.51,1.0	0.63±0.54,.09^{M}	0.51±0.53,.16	0.32±0.59,1.0	0.11±0.58,1.0	0.79±0.52,**.013**^{M}	0.91±0.53,**.003**^{M}
300-s period									
C vs G	0.95±0.60,**.009**^{M}	0.70±0.66,.11^{M}	0.31±0.65,1.0	0.86±0.71,.07^{M}	0.87±0.71,.07^{M}	0.86±0.68,**.03**^{M}	0.48±0.67,.48	0.52±0.64,.27	0.45±0.64,.36
C vs F	0.62±0.63,.15^{M}	0.58±0.70,.24	0.39±0.70,.71	0.17±0.73,1.0	0.18±0.73,1.0	0.69±0.74,.12^{M}	0.49±0.74,.53	0.23±0.66,1.0	0.37±0.66,1.0
G vs F	0.28±0.50,.84	0.08±0.58,1.0	0.14±0.58,1.0	0.60±0.58,.11^{M}	0.58±0.58,.12	0.18±0.61,1.0	0.03±0.60,1.0	0.83±0.54,**.016**^{M}	0.82±0.54,**.012**^{M}
Quarter 2 (Effect Size±95% Confidence Intervals, *P*)									
	Total distance	**Distance > 18 km·h^{-1}**	**Sprints > 18 km·h^{-1}**	**Accelerations > 2 m·s^{-2}**	**Decelerations > 2 m·s^{-2}**	**Distance > 21 km·h^{-1}**	**Sprints > 21 km·h^{-1}**	**Accelerations > 3 m·s^{-2}**	**Decelerations > 3 m·s^{-2}**
30-s period									
C vs G	0.74±0.55,**.021**^{M}	0.26±0.55,1.0	0.25±0.66,.38	0.48±0.54,.24	0.61±0.54,.06^{M}	0.08±0.60,1.0	0.10±0.60,1.0	0.45±0.57,.36	0.59±0.58,.12
C vs F	0.83±0.58,**.01**^{M}	0.27±0.59,1.0	0.67±0.69,1.0^{M}	0.04±0.57,1.0	0.02±0.57,1.0	0.12±0.62,1.0	0.16±0.61,1.0	0.46±0.61,.36	0.02±0.62,1.0
G vs F	0.13±0.46,1.0	0.50±0.48,.10	0.37±0.47,.34	0.44±0.46,.19	0.68±0.47,**.016**^{M}	0.20±0.52,1.0	0.26±.51,.99	0.96±0.50,**.001**^{M}	0.66±0.49,**.036**^{M}
60-s period									
C vs G	0.74±0.55,**.015**^{M}	0.23±0.55,1.0	0.36±0.56,.57	0.44±0.54,.34	0.39±0.54,0.40	0.23±0.60,1.0	0.12±0.60,1.0	0.39±0.54,.41	0.53±0.55,.14
C vs F	0.68±0.58,**.042**^{M}	0.33±0.59,.79	0.08±0.58,1.0	0.12±0.57,1.0	0.01±0.57,1.0	0.14±0.61,1.0	0.21±0.61,1.0	0.61±0.58,.14^{M}	0.41±0.58,0.60
G vs F	0.07±0.46,1.0	0.55±0.48,.06	0.42±0.47,.20	0.56±0.46,.06	0.49±0.46,0.20	0.36±0.51,.55	0.33±0.52,.66	1.01±0.47,<**.001**^{M}	0.95±0.48,<**.001**^{M}

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Table 5. Pairwise comparisons for the most demanding scenarios between playing positions within each game quarter

	Total distance	Distance > 18 km·h^{-1}	Sprints > 18 km·h^{-1}	Accelerations > 2 m·s^{-2}	Decelerations > 2 m·s^{-2}	Distance > 21 km·h^{-1}	Sprints > 21 km·h^{-1}	Accelerations > 3 m·s^{-2}	Decelerations > 3 m·s^{-2}
Quarter 2 (Effect Size±95% Confidence Intervals, *P*)									
120-s period									
C vs G	1.44±0.57,<**.001**^{L}	0.02±0.59,1.0	0.38±0.65,.32	0.31±0.58,.86	0.21±0.58,1.0	0.09±0.61,1.0	0.0±0.61,1.0	0.56±0.55,.12	0.48±0.56,.30
C vs F	1.42±0.61,<**.001**^{L}	0.36±0.63,1.0	0.04±0.61,1.0	0.08±0.51,1.0	0.23±0.61,1.0	0.14±0.62,1.0	0.21±0.62,1.0	0.42±0.59,.65	0.24±0.60,1.0
G vs F	0.27±0.45,.83	0.33±0.65,1.0	0.44±0.50,.22	0.42±0.51,.37	0.55±0.50,.22	0.23±0.54,1.0	0.21±0.53,1.0	0.94±0.49,**.001**^{M}	0.71±0.48,**.013**^{M}
180-s period									
C vs G	1.17±0.56,<**.001**^{M}	0.21±0.65,1.0	0.20±0.59,1.0	0.30±0.58,.82	0.12±0.57,1.0	0.21±0.62,1.0	0.20±0.63,1.0	0.72±0.57,**.037**^{M}	0.50±0.57,.32
C vs F	1.36±0.61,**.001**^{L}	0.17±0.62,1.0	0.24±0.61,1.0	0.12±0.60,1.0	0.22±0.60,1.0	0.06±0.64,1.0	0.03±0.64,1.0	0.17±0.60,1.0	0.19±0.61,1.0
G vs F	0.18±0.46,1.0	0.21±0.65,1.0	0.0±0.49,1.0	0.48±0.49,.24	0.45±0.49,.42	0.25±0.54,1.0	0.23±0.54,1.0	0.88±0.49,**.001**^{M}	0.67±0.49,**.021**^{M}
300-s period									
C vs G	0.51±0.56,.22	0.17±0.68,1.0	0.0±0.67,1.0	0.33±0.66,1.0	0.38±0.66,.99	0.03±0.66,1.0	0.18±0.66,1.0	0.66±0.60,0.10^{M}	0.64±0.62,.131^{M}
C vs F	0.56±0.59,.29	0.29±0.70,1.0	0.04±0.69,1.0	0.0±0.67,1.0	0.02±0.67,1.0	0.07±0.67,1.0	0.18±0.67,1.0	0.27±0.63,1.0	0.21±0.65,1.0
G vs F	0.01±0.47,1.0	0.06±0.54,1.0	0.04±0.54,1.0	0.39±0.53,1.0	0.44±0.53,.78	0.09±0.56,1.0	0.03±0.55,1.0	0.92±0.51,**.001**^{M}	0.86±0.51,**.003**^{M}
Quarter 3 (Effect Size±95% Confidence Intervals, *P*)									
	Total distance	**Distance > 18 km·h^{-1}**	**Sprints > 18 km·h^{-1}**	**Accelerations > 2 m·s^{-2}**	**Decelerations > 2 m·s^{-2}**	**Distance > 21 km·h^{-1}**	**Sprints > 21 km·h^{-1}**	**Accelerations > 3 m·s^{-2}**	**Decelerations > 3 m·s^{-2}**
30-s period									
C vs G	0.99±0.58,**.002**^{M}	0.38±0.57,.67	0.16±0.66,1.0	0.47±0.57,0.24	0.60±0.57,.09M	0.63±0.63,.21^{M}	0.46±0.63,.40	0.66±0.60,.11^{M}	0.36±0.60,.90
C vs F	1.08±0.60,**.002**^{M}	0.06±0.59,1.0	0.18±0.66,1.0	0.05±0.58,1.0	0.11±0.57,1.0	0.30±0.63,1.0	0.43±0.64,.49	0.18±0.61,.11	0.01±0.62,1.0
G vs F	0.01±0.47,1.0	0.30±0.48,.69	0.13±0.48,1.0	0.44±0.48,.18	0.78±0.48,**.008**^{M}	0.27±0.53,.96	0.03±0.53,1.0	0.47±0.50,.21	0.34±0.49,.59
60-s period									
C vs G	1.16±0.59,<**.001**^{M}	0.26±0.57,1.0	0.50±0.67,1.0	0.66±0.57,.11M	0.54±0.56,.19	0.63±0.63,.22^{M}	0.65±0.63,.12^{M}	0.51±0.20,.27	0.37±0.58,.80
C vs F	1.10±0.60,**.006**^{M}	0.14±0.59,1.0	0.38±0.67,1.0	0.06±0.58,1.0	0.13±0.57,1.0	0.32±0.64,.90	0.70±0.64,.10^{M}	0.02±0.57,1.0	0.24±0.58,1.0
G vs F	0.29±0.47,.65	0.12±0.48,1.0	0.06±048,1.0	0.55±0.48,.09	0.77±0.48,**.018**^{M}	0.24±0.53,1.0	0.04±0.54,1.0	0.47±0.48,.15	0.59±0.48,**.048**
120-s period									
C vs G	0.90±0.58,**.007**^{M}	0.05±0.62,1.0	0.08±0.60,1.0	0.26±0.62,1.0	0.40±0.62,.06	0.83±0.65,.06^{M}	0.53±0.64,.42	0.43±0.59,.36	0.54±0.59,.54
C vs F	0.87±0.60,**.013**^{M}	0.09±0.64,1.0	0.09±0.62,1.0	0.30±0.63,.95	0.33±0.64,.46	0.43±0.66,.46	0.35±0.66,.82	0.08±0.61,1.0	0.34±0.62,.42
G vs F	0.04±0.48,1.0	0.12±0.53,1.0	0.02±0.51,1.0	0.60±0.54,.12^{M}	0.84±0.55,**.019**^{M}	0.30±0.54,.92	0.12±0.55,1.0	0.52±0.49,.11	0.88±0.50,**.002**^{M}
180-s period									
C vs G	0.82±0.60,**.029**^{M}	0.0±0.63,1.0	0.43±0.64,.74	0.41±0.64,.68	0.30±0.64,.97	0.88±0.69,.09^{M}	0.61±0.68,.35^{M}	0.61±0.62,.16^{M}	0.61±0.64,.31^{M}
C vs F	0.80±0.61,**.032**^{M}	0.14±0.64,1.0	0.47±0.66,.38	0.14±0.64,1.0	0.23±0.64,1.0	0.40±0.69,.61	0.52±0.70,.34	0.13±0.64,1.0	0.17±0.66,1.0
G vs F	0.01±0.48,1.0	0.14±0.51,1.0	0.13±0.51,1.0	0.59±0.51,.11	0.66±0.51,.09^{M}	0.32±0.55,.80	0.01±0.55,1.0	0.49±0.50,.17	0.72±0.50,**.016**^{M}

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Table 5. Pairwise comparisons for the most demanding scenarios between playing positions within each game quarter

	Total distance	Distance > 18 km·h^{-1}	Sprints > 18 km·h^{-1}	Accelerations > 2 m·s^{-2}	Decelerations > 2 m·s^{-2}	Distance > 21 km·h^{-1}	Sprints > 21 km·h^{-1}	Accelerations > 3 m·s^{-2}	Decelerations > 3 m·s^{-2}
Quarter 3 (Effect Size±95% Confidence Intervals, *P*)									
300-s period									
C vs G	0.80±0.64,.051^{M}	0.04±0.68,1.0	0.25±0.68,.83	0.48±0.69,.69	0.28±0.68,1.0	1.10±0.72,**.023**^{M}	0.88±0.71,.12^{M}	0.51±0.68,.47	0.73±0.71,.23^{M}
C vs F	0.68±0.65,.16^{M}	0.13±0.69,1.0	0.22±0.70,.86	0.11±0.70,1.0	0.08±0.69,1.0	0.62±0.71,.16^{M}	0.60±0.71,.16^{M}	0.17±0.70,1.0	0.06±0.72,1.0
G vs F	0.13±0.48,1.0	0.09±0.54,1.0	0.0±0.55,1.0	0.29±0.54,.89	0.39±0.54,.59	0.28±0.56,1.0	0.04±0.56,1.0	0.32±0.51,.65	0.75±0.51,**.024**^{M}
Quarter 4 (Effect Size±95% Confidence Intervals, *P*)									
	Total distance	**Distance > 18 km·h^{-1}**	**Sprints > 18 km·h^{-1}**	**Accelerations > 2 m·s^{-2}**	**Decelerations > 2 m·s^{-2}**	**Distance > 21 km·h^{-1}**	**Sprints > 21 km·h^{-1}**	**Accelerations > 3 m·s^{-2}**	**Decelerations > 3 m·s^{-2}**
30-s period									
C vs G	0.59±0.61,.34	0.11±0.60,1.0	0.64±0.74,.86^{M}	0.37±0.60,.61	0.11±0.60,1.0	0.15±0.63,1.0	0.43±0.64,.61	0.29±0.62,1.0	0.07±0.62,1.0
C vs F	0.38±0.61,.88	0.12±0.62,1.0	0.35±0.69,.66	0.12±0.61,1.0	0.56±0.62,.34	0.29±0.67,1.0	0.07±0.67,1.0	0.41±0.64,.63	1.26±0.68,**.008**^{L}
G vs F	0.15±0.48,1.0	0.22±0.48,1.0	0.19±0.49,1.0	0.49±0.48,.13	0.62±0.48,**.037**M	0.17±0.56,1.0	0.34±0.55,.77	0.68±0.51,**.023**M	1.08±0.52,<**.001**^{M}
60-s period									
C vs G	0.51±0.60,.40	0.01±0.60,1.0	0.12±0.66,1.0	0.34±0.60,.86	0.16±0.60,1.0	0.28±0.63,1.0	0.0±0.64,1.0	0.30±0.60,.90	0.18±0.60,1.0
C vs F	0.22±0.61,1.0	0.20±0.62,1.0	0.23±0.66,1.0	0.18±0.62,1.0	0.56±0.62,.26	0.40±0.66,.78	0.26±0.66,1.0	0.38±0.61,.77	1.14±0.64,**.011**^{M}
G vs F	0.23±0.47,1.0	0.20±0.48,1.0	0.04±0.48,1.0	0.51±0.48,.11	0.68±0.49,**.014**^{M}	0.12±0.56,1.0	0.26±0.56,.93	0.68±0.49,**.020**^{M}	1.14±0.50,<**.001**^{M}
120-s period									
C vs G	0.97±0.61,**.041**^{M}	0.27±0.65,1.0	0.10±0.63,1.0	0.52±0.66,.46	0.56±0.66,.28	0.15±0.63,1.0	0.14±0.63,1.0	0.28±0.61,1.0	0.56±0.61,.27
C vs F	0.46±0.61,.27	0.01±0.65,1.0	0.12±0.64,1.0	0.02±0.67,1.0	0.38±0.67,.98	0.36±0.67,.85	0.32±0.67,.89	0.01±0.62,1.0	0.34±0.62,.82
G vs F	0.23±0.48,1.0	0.28±0.53,.88	0.02±0.52,1.0	0.49±0.55,.22	0.86±0.55,**.005**^{M}	0.23±0.55,1.0	0.49±0.56,.29	0.27±0.49,.78	0.86±0.49,**.002**^{M}
180-s period									
C vs G	1.10±0.63,**.038**^{M}	0.07±0.65,1.0	0.13±0.65,1.0	0.82±0.69,.09^{M}	0.63±0.68,**.045**^{M}	0.21±0.65,1.0	0.10±0.65,1.0	0.54±0.64,.33	0.68±0.64,.07^{M}
C vs F	0.35±0.63,.61	0.11±0.66,1.0	0.21±0.66,1.0	0.17±0.66,1.0	0.07±0.66,1.0	0.46±0.70,.56	0.34±0.69,.90	0.03±0.66,1.0	0.58±0.66,.51
G vs F	0.37±0.85,.34	0.17±0.65,1.0	0.02±0.52,1.0	0.52±0.52,.11	0.59±0.52,**.014**	0.28±0.57,.98	0.49±0.57,0.36	0.55±0.50,.10	1.19±0.53,<**.001**^{M}
300-s period									
C vs G	0.78±0.59,.06^{M}	0.06±0.65,1.0	0.23±0.68,1.0	0.88±0.73,.09^{M}	0.83±0.73,.07^{M}	0.04±0.65,1.0	0.15±0.66,1.0	0.58±0.64,.23	0.68±0.64,.07^{M}
C vs F	0.59±0.59,.27	0.15±0.70,1.0	0.09±0.70,1.0	0.38±0.71,.86	0.24±0.71,1.0	0.39±0.69,0.70	0.21±0.69,1.0	0.12±0.66,1.0	0.43±0.66,1.0
G vs F	0.20±0.49,1.0	0.20±0.66,1.0	0.31±0.56,1.0	0.38±0.55,.47	0.55±0.56,.11	0.38±0.58,.54	0.40±0.57,.62	0.46±0.51,.20	1.02±0.53,<**.001**^{M}

Note: Bolded P value indicates significant ($P < 0.05$) difference, ^{M} indicates moderate (0.6 – 1.19) effect size, ^{L} indicates large (1.2 – 1.99) effect size, C = Centres, G = Guards, F = Forwards.

Results of the statistical analyses between game quarters in guards are presented in Table 3. In guards, total distance was higher in Quarter 1 than Quarter 2 in the 180-s and 300-s periods and higher in Quarter 1 than Quarter 4 in the 300-s period ($P < 0.05$). The number of sprints >18 km·h^{-1} was higher in Quarter 1 than Quarter 2 in the 60-s period ($P < 0.05$). Accelerations and decelerations >2 m·s^{-2} were more frequent during Quarter 1 than Quarter 2 in the 180-s and 300-s periods, accelerations >3 m·s^{-2} were more frequent during Quarter 1 than Quarter 4 in the 180-s period, and accelerations >3 m·s^{-2} were more frequent during Quarter 1 than Quarter 2 in the 180-s period ($P < 0.05$).

Results of the statistical analyses between game quarters in forwards are presented in Table 4. In forwards, total distance was higher during Quarter 1 than Quarters 2 and 4 in the 180-s and 300-s periods ($P < 0.05$). All other differences were non-significant ($P > 0.05$), and the effect size magnitude ranged from trivial to moderate.

Results of the statistical analyses playing positions for each game quarter are presented in Table 5. In Quarter 1, total distance was higher in guards than centres in the 30-s, 60-s, and 300-s periods and higher in forwards than centres in the 30-s period ($P < 0.05$). Accelerations and decelerations >2 m·s^{-2} were more frequent in guards than forwards in the 60-s periods, and decelerations >2 m·s^{-2} were more frequent in guards than forwards in the 30-s period ($P < 0.05$). Distance >21 km·h^{-1} was higher in centres than guards for all sample durations ($P < 0.05$). Accelerations and decelerations >3 m·s^{-2} were more frequent in guards than forwards for all sample periods and more frequent in guards than centres in the 60-s period ($P < 0.05$).

In Quarter 2, total distance was higher in centres than guards and higher in forwards than centres in the 30-s to 180-s periods, and accelerations >2 m·s^{-2} were more frequent in guards than forwards in the 30-s period ($P < 0.05$). Accelerations and decelerations >3 m·s^{-2} were more frequent in guards than forwards for all periods, and accelerations >3 m·s^{-2} were more frequent in guards than centres in the 180-s period ($P < 0.05$).

In Quarter 3, total distance was higher in guards than forwards and centres in the 30-s to 180-s periods ($P < 0.05$). Decelerations >2 m·s^{-2} were more frequent in guards than forwards in the 60-s and 120-s periods, and distance >21 km·h^{-1} was higher in centres than guards in the 300-s period ($P < 0.05$). Decelerations >3 m·s^{-2} were more frequent in guards than forwards in the 60-s to 300-s periods ($P < 0.05$).

In Quarter 4, the total distance was higher in guards than centres in the 120-s and 180-s periods. Decelerations >2 m·s^{-2} were more frequent in guards than forwards in the 30–180-s periods and more frequent in guards than centres in the 180-s period ($P < 0.05$). Accelerations >3 m·s^{-2} were more frequent in guards than forwards in the 30- and 60-s periods ($P < 0.05$). Decelerations >3 m·s^{-2} were more frequent in guards than forwards for all sample periods and more frequent in centres than forwards in the 30- and 60-s periods ($P < 0.05$). All other differences were non-significant and trivial-small in magnitude ($P > 0.05$).

Discussion

In combination, the trends in our data support previous work in basketball highlighting reductions in MDS with game progression (Fox et al., 2020; Vázquez-Guerrero et al., 2020). A novel finding of this work is that in professional players, differences in MDS appear position-dependent and varied based on the external load variables and sample periods assessed.

Similar to previous research that used peak values to examine the differences between quarters (Fox et al., 2020; Vázquez-Guerrero et al., 2020), this investigation suggests that decreases in the MDS are evident across basketball games, with differences most prevalent between Quarters 1 and 2 over longer periods (≥120 s) across all playing positions. Our findings also revealed more accelerations and decelerations >2 m·s^{-2} in the 180 and 300-s periods during Quarter 1 compared to Quarter 2, reflecting the data obtained in elite under-18 basketball players (Vázquez-Guerrero et al., 2020). Given that much of the physical stimulus imposed on basketball players is a result of intermittent, physically demanding movements, such as accelerations, decelerations, and change of direction (Stojanović et al., 2018), these variables are likely more sensitive to changes in external load, with respect to fluctuations in the MDS. Consequently, assessing high-intensity (>2 m·s^{-2}) accelerations when quantifying the MDS of training and match-play may be of particular importance to practitioners when prescribing and manipulating the external training load of players.

Although a trend emerged for MDS to decrease across the game, it is important to note that in some instances (e.g., distance >18 and >21 km·h^{-1} for guards and forwards over varied sample periods), the highest MDS occurred in later game periods (Quarters 3 and 4). While past work has suggested that decreases in MDS may be related to fatigue-related mechanisms (Fox et al., 2020), the findings of this study suggest that it may be more closely related to outcomes such as tactical strategies and game-related contextual factors (e.g., level of opposition, score-line margin, win vs loss). As such, further research investigating the influence of tactics and contextual factors on MDS in basketball may be particularly useful in understanding potential mechanisms explaining fluctuations in MDS in basketball to further assist in more precise training prescription and manipulation.

When assessing the influence of playing position, the current investigation supports previous work (García et al., 2020; Vázquez-Guerrero et al., 2020), demonstrating position-dependent external load profiles in basketball. For instance, total distance was significantly lower in centres than guards and forwards during different periods in all four quarters. These results may partly be explained by a combination of technical and tactical profiles along with the anthropometric characteristics of players. Specifically, centres are required to play near the three-second zone, set screens and rebound during set-pieces (Sampaio et al., 2006) and are usually the tallest and heaviest players (Gryko et al., 2018), making them suited to positions with lower movement demands.

Accelerations and decelerations >2 and >3 m·s^{-2} also presented great variation between playing positions. Specifically, guards completed more accelerations and decelerations during all four quarters, presumably because they are required to perform a great number of intermittent, high-intensity movements (e.g., changes of direction) in half and full-court situations (e.g., cutting, perimeter play, defence, etc.). In interpreting this finding, it is also important to consider that some differences in MDS detected in the >3 m·s^{-2} were not apparent when assessing the number of accelerations and decelerations >2 m·s^{-2}. Given that elite under-18 male basketball players

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have performed peak accelerations up to 3.6 $m \cdot s^{-2}$ during official games (Vázquez-Guerrero, Jones, et al., 2019), it is possible that the 2 $m \cdot s^{-2}$ threshold typically utilised does not reflect a true high-intensity effort when assessing accelerations and decelerations. Moreover, in basketball, the cut point used to assess "high-intensity" activity using inertial sensors appears to be somewhat arbitrary and often comes from the sensors' proprietary software rather than an evidence-based approach. As such, further work assessing the appropriateness of varied cut points to discriminate between intensities of accelerations and decelerations in basketball appears particularly valuable.

In conclusion, this study showed that the MDS of basketball match-play fluctuates across game quarters and varies between playing positions in professional players. Nevertheless, when interpreting the findings of this study, some notable limitations should be acknowledged. The small sample per position might limit the representativeness of the external loads encountered within each positional group. Finally, only the MDS of different physical demand parameters were measured for each player in isolation which does not take into account important contextual factors, such as activities completed by team-mates and opponents within the same game period as well as outcomes relating to tactical strategies, score-line margin, and the game results (e.g., whether the team was winning or losing). Therefore, future research should expand the analysis of the MDS during different competition formats (e.g., pre-season, tournament, play-off) while considering game-related contextual factors (e.g., offence, defence, transitions, score) to understand fluctuations in MDS of basketball match-play better and consequently optimise training prescription and player performance.

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ORIGINAL SCIENTIFIC PAPER

The Relative Age Effect on Athletes of the Santa Catarina Basketball Federation

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Abstract

This study analyses the relative age effect (RAE) in basketball athletes, considering the categories (U13, U15, U17, and U19), sex, number of games and average points. The participants were 1,455 Brazilian athletes aged between 9 and 19 who participated in the Santa Catarina State Basketball Championship in the 2018 season. To test the RAE, the Chi-square test (χ2) was performed to compare the observed distribution and expected birth quartiles. To verify the differences between the birth quartiles concerning the average of points and the number of games, One-Way ANOVA with post hoc Bonferroni was applied. The effect size was verified using Eta^2. Odds Ratios and confidence intervals were calculated for all birth quartiles. In conclusion, it was found that, in the general sample of players participating in the Santa Catarina State Basketball Championship, there was an over-representation of players born in the first two quarters of the year in most of the categories analysed. However, significant differences were found in the number of games and average points only in male players in the U13 category. These results confirm that the player selection process is negatively biased towards boys born at the end of the year in the U13 category.

Keywords: *relative age effect, youth sport, athlete development, birthday distribution*

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Introduction

Performance in basketball, as in other sports, is influenced by several individual (date of birth, maturation) and environmental (sports system and culture) factors (Hancock et al., 2013). In several modalities, sports categories are composed by the grouping of athletes by annual age groups established by sports organizations (Lago-Fuentes et al., 2020). The well-intentioned objective is to provide equal opportunities and competition (Huertas et al., 2019; Lupo et al., 2019). However, there may be a difference (chronological and biological) of up to 12 months between children and adolescents born in the same year (Lago-Fuentes et al., 2020) and of up to 24 months for those who participate in competitions composed of players born in two consecutive years (Saavedra & Saavedra, 2020; Ibáñez et al., 2018). Such differences play a fundamental role in the level of development of athletes, consequently influencing their sports performance in the early stages of sports training.

The age difference between individuals in a given group

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concerning a cut-off point is known as Relative Age. In contrast, this difference can produce the potential advantage known as the Relative Age Effect (RAE) (Saavedra & Saavedra, 2020). In this case, the RAE is associated with the participation and performance advantages of chronologically older athletes concerning younger athletes within the same age category due to their greater physical, cognitive, and emotional development (Sierra-Díaz et al., 2017; Ibáñez et al., 2018). Thus, in the early stages of sport development, older athletes tend to have more excellent representation and the possibility of accessing environments that improve their skills (Saavedra & Saavedra, 2020; Oliveira et al., 2019).

On the international scene, investigations aimed at understanding the RAE in the representation of basketball athletes in youth competitions have revealed a better representation of athletes born in the first months of the year (Vegara-Ferri et al., 2019; Ibañez et al., 2018; Torres -Unda et al., 2016), especially in the initial categories. In contrast, studies carried out with athletes from adult categories have not found significant differences between the months of the year and the representation of athletes born in the first or last months of the year (Vegara-Ferri et al., 2019; Esteva et al., 2006; Baker et al., 2009). Such studies reinforce the evidence that RAE is more highly prevalent in youth teams (Jackson & Comber, 2020; Ibáñez et al., 2018) than in adult teams (Brustio et al., 2018; Doyle & Bottomley, 2019).

The results found in most international research corroborate the inference that the selection (representation) of basketball athletes based on advantages related to dates of birth are smoothed or eliminated when players reach full maturation in late adolescence (Ibañez et al., 2018). However, research carried out in Spanish elite basketball found that RAE is present in professional teams due to the selection of athletes born in the first quarters of the year (with superior maturation and physical development) during the training period. (Esteva et al., 2006).

Concerning the performance of athletes in disputed competitions, García et al. (2014) found minor variations, although these differences did not coincide with the existence of RAE. As for sex, Arrieta et al. (2015) and Brazo-Sayareda et al. (2018) found a higher prevalence of RAE in male athletes compared to females. These results reinforce the finding that RAE is highly prevalent in male athletes, especially when the sport demands are physical and high in popularity and a high level of competitive selection among teams is present (Brazo-Sayareda et al., 2018). In contrast, Leite et al. (2013) did not find significant RAE values related to the sex of the athletes.

Brazilian studies carried out with youth athletes present evidence similar to those found in the international literature. The results have shown a better representation of athletes born in the first months of the year and a more significant presence of RAE in male than female athletes (Oliveira; Ribeiro Júnior; Vianna et al., 2017; Oliveira; Ribeiro Júnior; Werneck et al., 2017). These data corroborate the indication by Arrieta et al. (2015) that, in a sporting season, athletes who matured earlier have advantages in sports performance. Oliveira, Ribeiro Júnior, Vianna et al. (2017) highlight that the selection of athletes based on physical aspects related to performance and the grouping of players into age categories with an age difference of up to 24 months is the primary responsibility for RAE in competitions for young athletes, especially in Brazil.

A study carried out with athletes who competed in the major Brazilian adult competitions showed the presence of the RAE, but in an inverted form in athletes aged 25 to 34 years and the absence of the effect for those who were in the final phase of their career (Oliveira et al., 2019). For Oliveira et al. (2019, p. 7), the inversion of RAE in athletes who are in the consolidation phase in Brazilian basketball (higher proportion in the 3rd quartile) may "[…] be associated with a compensatory effect of technical, tactical and psychological skills that were not developed in athletes born in the first months of the year". That indicates that many athletes who reach this stage of career development have disabilities that do not allow them to remain at the highest level of their adult careers. Furthermore, the finding of maintenance of the RAE in adult competitions corroborates the indication of Esteva et al. (2006) that this is a consequence of the previous selection carried out in the training categories.

Based on the theoretical support presented, very few publications focused on the RAE on Brazilian athletes from training categories (Oliveira; Ribeiro Júnior; Vianna et al., 2017), primarily encompassing athletes participating in all youth competitions of federation state sports. Furthermore, we do not know of studies that analysed this theme, relating the representativeness of athletes born at different times of the year with participation in games and the average of points converted in the games played. In this scenario, this study aimed to analyse the relative age effect in basketball athletes, considering the categories (U13, U15, U17, U19), sex, number of games and average points.

Methods

Study design and participants

This study is characterized as cross-sectional. A total of 1.455 Brazilian athletes aged between 9 and 19 years (14.37 ± 2.0 years) participated in the research. Of these, 503 were female, and 952 were male, who participated in the Santa Catarina State Basketball Championship (Brazil) in the 2018 season. State championships (U13 to U19) are organized by the Santa Catarina Basketball Federation (FCB) and involve basketball clubs from all six Santa Catarina/Brazil regions. Phases organize the competitions: qualifying (turn and return, classifying eight teams); semi-final (octagonal, all against all, classifying four teams); and final (foursquare all against all). It is noteworthy that the FCB, among the federations affiliated to the Brazilian Basketball Confederation (CBB), stands out with a consolidated federation, which annually holds regional, state and interstate tournaments, in addition to participating (with significant results) in national competitions promoted by CBB (FCB, 2019, 2020). In 2018, 43 teams participated in these competitions, in categories U13 (n = 588 athletes), U15 (n = 435 athletes), U17 (n = 264 athletes) and U19 (n = 168 athletes). Some investigated athletes who participated in competitions in categories above their age, but these athletes were analysed only in their category of origin (relative to their chronological age).

Data collection procedures

Information was obtained from three document sources. Information regarding the sex and date of birth was obtained from the FCB's official website (https://www.basket-fcb.com.br/). The tabulation of these data was carried out between March and September 2019. The information regarding the number of games played and the athletes' scores in compe-

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titions was tabulated between June and December 2019, obtained from the match summaries provided by the president of the FCB, as they were not available on the federation's official website. Informed consent or approval from the Ethics Committee was not required to carry out the study, as it is public domain data accessible online (Maciel et al., 2021; Saavedra & Saavedra, 2020). In addition, there is no explicit or implicit prohibition on that website that would make the use of data for academic and scientific purposes unfeasible. Nevertheless, all data were treated together, without reference to the names of teams and players.

Statistical Analyses

To test the RAE, the Chi-square test ($\chi2$) was performed to compare the observed and expected distribution in the birth quartiles (categorized by the athletes' birth quarter - Q1: January to March, Q2: April to June, Q3: July to September, Q4: October to December and by sex (female and male)). Expected frequencies were based on the birth rate evenly distributed throughout the year. This choice was made due to the difficulty accessing birth statistics for each population studied (Cobley et al., 2009). Sharpe (2015) suggested that the standardized residual was also calculated and interpreted as significant when greater than z> | 2.0 |. To verify the differences between the birth quartiles concerning the average of points and the number of games, One-Way ANOVA with post hoc Bonferroni was applied. The effect size was verified using Eta². All tests were performed using the IBM SPSS 20.0 software (Inc, Chicago, IL, USA), and the significance level was set at $p<0.05$. Odds Ratios (ORs) and confidence intervals were calculated for all birth quartiles, considering the categories (U13, U15, U17 and U19) of both sexes.

Results

Figure 1 shows the distribution of athletes into birth quartiles according to sex. Differences were found in the birth quartile of athletes of both sexes in the U13 category. The standardized residuals showed significant results in the last birth quartile of the female U13 category (z=-2.6), showing a birth frequency of athletes below expectations. In contrast, in the male U13 category, the results were significant in the first three birth quartiles (z=8.2; z=7.2; z=5.6), revealing a frequency of athletes higher than expected. In the U15 and U19 categories, the RAE was found only in male athletes. More athletes were born in the first two quartiles of the year, except for female U19 athletes.

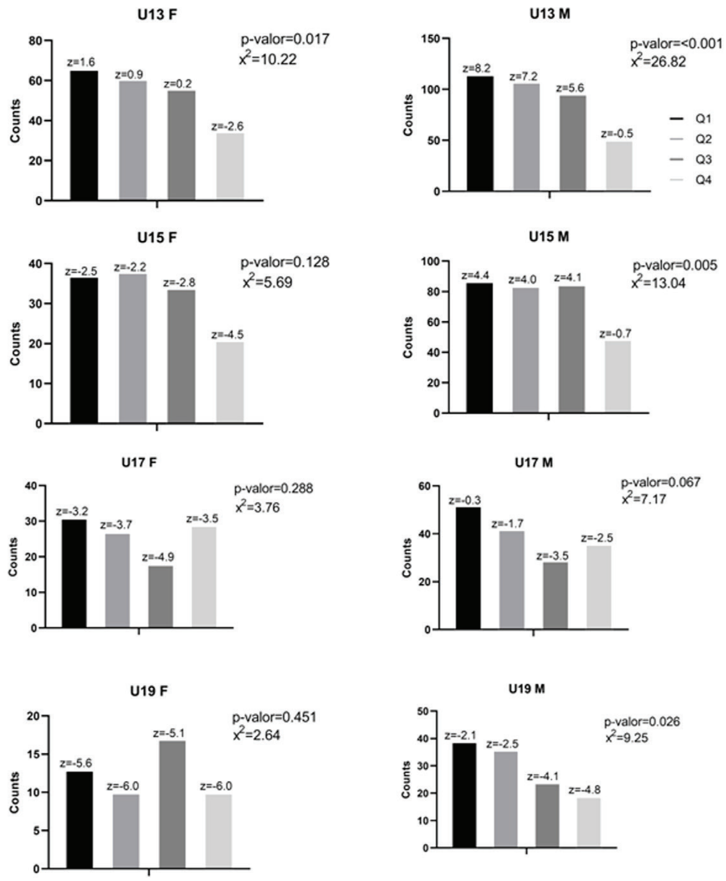

Figure 1. Relative age effect in relation to a category according to sex.
F = female; M = male; Q1-Q4 = birth quarter; X2 = Chi-square; z = Std. Residual.

The comparison between the number of games per birth quarter, according to category and sex, is shown in Table 1. Athletes aged up to 13 years, born in the first months of the year, participated in more games than younger athletes within the same age category (p=0.033). The results were not significant in the other categories. However, from the U15 category onwards, there is a tendency for athletes born in the last quarter of birth to be equivalent or even to perform a more significant number of games than older athletes, revealing a decrease in the RAE concerning the number of games played.

Table 1. Comparison between the number of games per quarter of birth, by category and sex

	Q1	Q2	Q3	Q4	Total	F	Sig.	Eta²
U13								
Female	6.94 (3.54)	6.84 (3.52)	6.54 (3.52)	6.31 (3.19)	6.71 (3.46)	0.320	0.811	0.067
Male	7.23 (3.58)	7.08 (2.87)	6.74 (3.39)	5.67 (3.15)	6.84 (3.30)	2.934	0.033	0.153
U15								
Female	5.08 (2.99)	5.97 (2.89)	6.12 (3.16)	7.10 (3.85)	5.94 (3.19)	1.880	0.136	0.207
Male	4.38 (2.04)	4.05 (1.94)	4.18 (2.07)	3.76 (2.13)	4.13 (2.04)	1.043	0.374	0.101
U17								
Female	5.87 (3.22)	6.37 (3.18)	6.61 (2.91)	5.66 (3.30)	6.07 (3.16)	0.457	0.713	0.116
Male	7.87 (3.94)	7.93 (2.87)	7.38 (3.69)	6.86 (3.57)	7.57 (3.55)	0.765	0.515	0.121
U19								
Female	4.08 (2.29)	4.10 (2.76)	4.29 (2.33)	5.10 (1.91)	4.36 (2.30)	0.442	0.724	0.164
Male	6.82 (3.89)	5.81 (2.66)	5.96 (4.07)	6.84 (3.23)	6.34 (3.48)	0.751	0.524	0.139

Note. Q1-Q4 = birth quarter; Sig. = significance; Eta2 = eta squared.

Table 2 shows the comparison between mean points and birth trimester, considering the category and sex of the athletes. There is a significant association only in the U13 category ($p<0.05$) male. In other words, older athletes have a higher average of points compared to younger athletes. Although not significant, this trend persists in the other male categories, while in the U15 and U19 women's categories, younger athletes have a higher average score than older athletes.

Table 2. Comparison between the average of points per quarter of birth, by category and sex

	Q1	Q2	Q3	Q4	Total	F	Sig.	Eta²
U13								
Female	4.02(5.10)	3.48 (4.73)	2.54 (6.17)	3.06 (4.43)	3.33 (5.20)	0.863	0.461	0.106
Male	4.92 (6.06)	3.38 (3.79)	3.75 (4.46)	1.76 (2.55)	3.73 (4.75)	5.725	0.001	0.212
U15								
Female	3.05 (3.71)	2.47 (3.69)	4.29 (4.87)	3.52 (3.06)	3.28 (3.97)	1.338	0.265	0.176
Male	4.87 (5.76)	5.17 (5.85)	4.52 (5.97)	3.22 (3.76)	4.59 (5.59)	1.355	0.257	0.115
U17								
Female	5.48 (6.02)	4.63 (4.74)	4.17 (4.28)	4.69 (5.04)	4.82 (5.11)	0.284	0.837	0.092
Male	5.29 (5.13)	5.31 (5.62)	4.48 (4.79)	5.14 (4.95)	5.11 (5.12)	0.184	0.907	0.06
U19								
Female	4.46 (5.86)	5.10 (5.36)	7.00 (6.82)	6.80 (6.23)	5.92 (6.11)	0.537	0.659	0.184
Male	6.54 (5.51)	5.42 (5.53)	6.08 (6.06)	5.11 (4.55)	5.87 (5.45)	0.409	0.747	0.103

Note. Q1-Q4 = birth quarter; Sig. = significance; Eta2 = eta squared.

The results of the ORs are shown in Table 3. The sample did not reveal significant ORs for all comparisons.

Table 3. Unadjusted odds ratios (ORs) according to the RAE in the category

	OR comparisons (95% CI)		
	Q1 vs Q4	Q2 vs Q4	Q3 vs Q4
U13	1.74 (0.69-1.97)	1.23 (0.72-2.11)	1.25 (0.72-2.15)
U15	0.98 (0.57-1.69)	1.09 (0.63-1.90)	1.20 (0.68-2.10)
U17	0.71 (0.40-1.45)	0.66 (0.37-1.18)	0.51 (0.27-1.93)
U19	0.62 (0.25-1.41)	0.99 (0.25-2.00)	0.90 (0.81-1.43)

Note. Q1-Q4 = birth quarter; OR = chance ratio; CI = confidence interval.

Discussion

Similar to previous studies that analysed the presence of RAE in young players, we observed a higher proportion of athletes born in the first two quarters of the year (Ibáñez et al., 2018; Torres-Unda et al., 2016; Vegara-Ferri et al., 2019). However, it is noteworthy that some substantial differences were found mainly in the U13 category and among male athletes.

The U13 is characterized as one of Brazil's first competitive basketball categories for athletes up to 13 years old. In this category, players usually have their first contact with formal games and competitions and experience competitive experiences. However, the search for immediate success arising from strategic and organizational factors of clubs and training centres (De Bosscher & De Rycke, 2017; Ribeiro Júnior et

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al., 2019) has resulted in a phenomenon called “maturation selection”, in which chronologically older players are chosen because of their superior physical, anthropometric, and performance qualities (Campos et al., 2020) compared to younger players.

Our results are consistent with the results found by Ribeiro Júnior et al. (2020), who also found the presence of RAE in basketball players in the initial categories (U12, U13), with a more significant number of individuals born in the first and second trimester of the year. According to Oliveira et al. (2019), this more significant representation of players born in the first months of the year is more evident in younger categories, when athletes have wider biological and maturational variability. However, our evidence does not corroborate other studies that found the RAE in the U15 and U17 categories of basketball teams participating in the Brazilian Club Championship (CBC) (Oliveira, Ribeiro Júnior, Vianna, et al., 2017; Oliveira, Ribeiro Júnior, Werneck, et al., 2017) and U17 and U19 of the world’s elite teams of the sport (Vegara-Ferri et al., 2019).

In the RAE and the number of games played and in the average of points, the differences were more significant in boys from the U13 category. The results found in the study with athletes who participated in the CBC revealed that high stature players in the U13 category surpassed the average height of the U14 category players (Ribeiro Júnior et al., 2020). Thus, even though the players’ body size was not inferred in this study, it can be said that because the differences in body height concerning the quarter in which the player was born are even more visible in the younger categories, taller players in the basketball is more likely to hit the basket and, consequently, score more points during matches (Rubajczyk et al., 2017), leading them to be called up for more games.

In a study carried out with French basketball players aged eight to 18 years, evidence showed that those born in the first semester of the year had greater body height in all categories when compared to their younger peers (Delorme & Raspaud, 2009). Similarly, evidence found in the study carried out with Polish athletes showed that U14 players born in the first months of the year have greater body height and better performance than younger players within the same category (Rubajczyk et al., 2017). Therefore, players matured earlier, especially when the biological and maturational transformations inherent in the transition from childhood to adolescence are more prevalent, are generally taller, more muscular and demonstrate more refined abilities and skills than younger players within the same age category (Campos et al., 2020).

In this study, significant differences were found mainly among male Brazilian players. According to Lidor et al. (2014), one reason why the RAE is superior in male players is the imbalance in the number of players, teams, and popularity of basketball nationwide between the sexes. This statement has been confirmed in Brazilian studies, firstly due to the absence of an intermediate national championship between the U17 and adult female category for an extended period (Oliveira, Ribeiro Júnior, Werneck, et al., 2017), and secondly, due to the difference in the number of male (79) versus female (52) teams enrolled in the State Championship of Santa Catarina in the year in which the information for this study was collected. However, this finding is specific to the Brazilian context and cannot be generalized to other countries.

In the female categories, RAE was present only in U13 players, confirming evidence from other studies that reduced the effect in older female categories (Ferreira et al., 2020; Rubajczyk et al., 2017; Sierra-Díaz et al., 2017). In addition to the prevalence of a more significant number of male athletes, differences in the distribution of birth dates and body height of basketball players are less visible than in boys, as puberty dynamics differ between the sexes (Brazo-Sayavera et al., 2018; Rubajczyk et al., 2017). Thus, it is necessary to create solutions to minimize the presence of the RAE as a function of sex in youth basketball (Rubajczyk et al., 2017), favouring equality of participation and competition in the sport.

Concerning the number of games and the average of points, different results were found by Arrieta et al. (2015) in the study carried out with elite basketball players from the Spanish league, which found the RAE in players from the older categories (U16, U18, U20), who had a long time of participation in games, higher number of points and superior performance level when compared to younger players. The Brazilian categories U15, U17 and U19 did not show significant differences in the number of games and average points, demonstrating a more homogeneous pattern in players’ performance in these categories, which is the opposite of what was seen in the study of the Spanish players.

According to Jackson and Comber (2020), the RAE loses strength as athletes approach the adult categories, and the representation of players based on advantages related to birth dates are smoothed or eliminated when youngsters reach full maturation in late adolescence (Arrieta et al., 2015; Ibáñez et al., 2018). In this case, the influence of relative age differences that benefited those born at the beginning of the year tends to decrease as players mature mentally and physically (Rubajczyk et al., 2017).

For this reason, there must be a sporting process designed and executed in the long term, as the players who stand out in the initial categories will not always be the same ones who will remain prominent in the adult categories. Previous studies have observed that younger players (born closer to the deadline) have longer professional careers when compared to their older peers. (Lago-Fuentes et al., 2020; Rubajczyk & Rokita, 2018).

Finally, it should be noted that the selectivity around players considered talented who matured earlier can increase the dropout rate of young players born in the last months of the year. Therefore, training and competition opportunities must be ample and favour the permanence of young people, especially in the initial categories, without the early selection processes causing losses and consequent abandonment of sports practice.

It is believed that, regardless of the month of birth and sex, all athletes should have equal opportunities for sports development because the more comprehensive the practice opportunities, the greater the chances of long-term sporting success, whether in the sport of high performance or participation sport for life. Therefore, only a longitudinal approach, which consists of monitoring athletic performance throughout the athlete’s entire sports career, would be able to confirm whether the RAE is prevalent in all categories and provides better performance over time, favouring those who are more biologically advanced, who have advantages, often temporary, concerning other (Ribeiro Júnior et al., 2019).

This work has several limitations. First, only the number of games and the average points of the games were considered for analysis. Other physical (speed, skill) and anthropometric (weight, height) variables could contribute to a greater understanding of the effects of the RAE on Brazilian players. Secondly, this study concerns only analysing the distribution of birth dates in youth basketball, without considering the adult male and female categories. Finally, only one sporting season was considered; the monitoring of several competitive seasons could add important information about the RAE relationship with the performance of athletes over time.

In conclusion, it was found that there was an over-representation (RAE) of players born in the first two quarters of the year in most of the categories analysed in the general sample of players participating in the Santa Catarina State Basketball Championship. However, we found significant differences in the number of games and average points only in male U13 players. These results confirm that the player selection process is negatively biased towards boys born at the end of the year in U13.

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ORIGINAL SCIENTIFIC PAPER

Physical Activity and Sedentary Behaviour in Croatian Preschool Children: A Population-Based Study

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Abstract

This study aimed to determine the differences in physical activity and sedentary behaviour in preschool children living in different geographical regions. Preschool children (N=1625) and their parents from different parts of Croatia, from urban and rural settlements, participated in this cross-sectional, population-based study. Parents completed the Netherlands Physical Activity Questionnaire (NPAQ), a measure of physical activity and sedentary behaviour in children. The main results of this study show differences in physical activity and sedentary behaviour in preschool children living in four geographical regions in Croatia ($F=4.45$; $p<0.01$). The least physically active are children from a continental area that gravitates to the capital city, while the most active are children from a southern coastal region. Sedentary behaviour is the greatest in the rural eastern Croatian continental region. Higher physical activity and lower sedentary activities in young children living in coastal compared to continental regions show possible specific advantages of Mediterranean climate in general. The practical importance of information obtained in this study is a need for a specific intervention strategy for improving physical activity in continental preschool institutions.

Keywords: *kindergarten, Mediterranean, screen-time, rural, urban*

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Introduction

Physical inactivity is recognized as the biggest public health problem of the 21st century. To prevent obesity and other non-communicable diseases, physical activity, increased physical fitness, and reduced sedentary behaviour are crucial. Various public health actions are being taken to raise awareness of the importance of physical activity. Public health initiatives to promote physical activity use a multisector, multisystem approach. Schools and sports clubs play a major role in these initiatives by providing physical activity for children and offering programmes to develop knowledge and skills for healthy and active living habits (Investments that Work for Physical Activity, 2012).

Health institutions worldwide have made recommendations regarding the necessary daily amount of physical activity for children. For preschool children, Canada

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(Tremblay et al., 2012), the United Kingdom (Department of Health, 2011), and Australia (Department of Health and Aging 2010) recommend up to 180 minutes of physical activity per day. National recommendations for Croatia proposed by Jurakic and Pedisic (2019) are in line with the latest World Health Organization (WHO) guidelines for preschool children (WHO, 2019). It is generally recommended that at least 60 minutes out of these 180 minutes of various physical activities are spent in moderate-to-vigorous play.

In addition to the physical activity guidelines, some countries have also set guidelines for sedentary behaviour in preschool children. Children from one to five years of age should not engage in sedentary activities for more than one hour a day (excluding sleep time). Furthermore, one- to two-year-old children should not have any screen time (TV, computer, or mobile phone), while for children aged three and four, this time should be limited to the maximum of one hour per day. If children spend time in sedentary activities, it is recommended that this time be devoted to reading and storytelling or other types of intellectual and fine motor development activities (WHO, 2019; Jurakic& Pedisic, 2019).

Published research on the level of physical activity and sedentary behaviour in preschool children shows that the physical activity is generally lower and that the sedentary behaviour is generally higher than the abovementioned recommended time values. For example, according to Tucker´s review (2008) of studies from seven countries (four of which European), involving 10,316 preschool children aged 2 to 6, almost half of the children did not reach the recommended daily level of physical activity for their respective age. In contrast, a study of preschool children conducted in Britain by Hall and co-authors (2018) found that 80.30% of them did achieve the recommended daily level of physical activity. Another study, by Barbosa and Oliveira (2016), showed that preschool children spend much time in sedentary activities (even during their stay in kindergartens) and that sedentary activities are more frequent when children are indoors (up to 94% of the time) compared to when they are outdoors (Barbosa & Oliveira, 2016).

To successfully implement a physical activity promotion system in a specific setting (country, region, culture), it is important to understand the factors on which the physical activity depends. These factors vary from childhood to adulthood. According to relevant research, the level of physical activity of preschool and early school-age children largely depends on gender, age, self-confidence in movement, physical engagement in certain situations, family support, history of premature birth, kindergarten environment and the father's body mass index (BMI) (Bauman et al., 2012; Finn et al., 2002; Barbosa & Oliveira, 2016). Furthermore, it seems that as the children grow older, the time spent in medium- to high-intensity physical activity decreases, while the time spent in low- to medium-intensity physical activity increases (Barbosa & Oliveira, 2016). This shows that growing up weakens the intensity of physical activity gradually, and it is thus very important to motivate and involve preschool children in various forms of physical activity from an early age. Doing so could be seen as the responsibility of a variety of educational and health institutions.

According to the World Health Organization data for the Republic of Croatia (WHO, 2018), 88% of children aged 8 meet the recommended values of physical activity (60 minutes), but this percentage decreases to only 19% in adolescents (WHO, 2018). Therefore, one would expect preschool children to meet the recommended level of physical activity, but the study by Petric et al. (2019) conducted on a small sample of Croatian preschool children found that that was not the case. These children did not meet the daily recommended level of physical activity (180 minutes). Although the physical activity of school-aged children in Croatia has been studied before (Janssen et al., 2005), this study presents physical activity and sedentary behaviour in Croatian preschool children of three to six years of age.

This study aims to determine the differences in physical activity levels and sedentary behaviour in preschool children of different ages, sexes, and places of residence in Croatia.

Methods

A total of 1,625 preschool boys and girls aged 3 to 6 from different parts of Croatia participated in this study (Table 1). Since this research was a part of a larger study, the sample size was larger than the minimal recommended (Raosoft sample size calculator). The average age of the participants was 5.2 years. The Republic of Croatia is divided into four geographically and economically different macro-regions (the largest is the Central or Zagreb macro-region (50% of the population), followed by the Dalmatian or Split macro-region, the Eastern Croatian or Osijek macro-region and the Northern Croatian coast or Rijeka macro-region). Based on the official 2011 census of the State Bureau of Statistics (the total of 166,439 children) and the proportion of the preschool children population in the population of each region (48% for Zagreb macro-region, 22% for Rijeka macro-region, 18% for Osijek macro-region and 12% for Split macro-region), the size of the sample for each region was calculated. Based on the initial proportions, the kindergartens included in the study were randomly selected from the official governmental list. Therefore, all children from these kindergartens were included in the measurements.

Measurements

This study was conducted from September 2018 to May 2019 as a part of a larger research project on motor skills in preschool children in Croatia. The physical activity and sedentary activities of preschool children were evaluated by their parents using "The Netherlands Physical Activity Questionnaire" (NPAQ) (Janz et al., 2005), which was adapted to the Croatian language (Kezic & Miletic, 2014; Culjak et al., 2014). NPAQ is a Likert-type questionnaire consisting of seven questions about a child's physical activity scaling responses on a scale of 1 to 5. It is a simple and practical measure of everyday physical activity preferences in young children, which has moderate to good reliability (Janz et al., 2005). Physical activity results are reported as an average score of seven questions, while sedentary behaviour (average hours spent watching TV, using computers and mobile phones) is expressed in minutes per day (Janz et al., 2005). Questionnaires were filled out by mothers (83.51% of the cases), fathers (15.02% of the cases) or others (i.e., both mother and father, grandmother, foster mother or not specified) (1.47% of the cases).

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Table 1. Sample distribution according to regions, gender and age (number (percentage)

	Zagreb		Rijeka		Osijek		Split		Total
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	
N	480 (29.54%)	357 (21.97%)	152 (9.35%)	169 (10.4%)	147 (9.05%)	102 (6.28%)	139 (8.55%)	99 (6.09%)	1625 (100%)
Male	263 (16.19%)	191 (11.75%)	76 (4.68%)	83 (5.11%)	76 (4.68%)	45 (2.77%)	73 (4.49%)	50 (3.08%)	857 (52.74%)
Female	217 (13.35%)	166 (10.22%)	76 (4.68%)	86 (5.29%)	71 (4.37%)	57 (3.51%)	66 (4.06%)	49 (3.02%)	788 (48.49%)
Age 3	92 (5.66%)	43 (2.65%)	32 (1.97%)	42 (2.59%)	27 (1.66%)	13 (0.8%)	31 (1.91%)	18 (1.11%)	298 (18.34%)
Age 4	124 (7.63%)	92 (5.66%)	40 (2.46%)	61 (3.75%)	42 (2.59%)	20 (1.23%)	48 (2.95%)	31 (1.91%)	458 (28.19%)
Age 5	86 (5.29%)	88 (5.42%)	49 (3.02%)	41 (2.52%)	28 (1.72%)	28 (1.72%)	34 (2.09%)	24 (1.48%)	378 (23.26%)
Age 6	164 (10.09%)	131 (8.06%)	31 (1.91%)	25 (1.54%)	50 (3.08%)	38 (2.34%)	26 (1.6%)	26 (1.6%)	491 (30.22%)

Data analysis

Statistical analyses were performed using TIBCO Statistica v.13 software (TIBCO Statistica Inc, OK, USA). Differences in the degree of physical activity and sedentary behaviour of the preschool children of different ages and from different regions were determined using the analysis of variance (one-way and two-way ANOVA) and the unequal N HSD post hoc test. Statistical significance was set to $p<0.05$.

Results

The physical activity of preschool children significantly differs among the four macro-regions in Croatia ($F=9.41$; $p<0.01$) (Table 1). There were no significant differences in the preschool children's physical activity in different types of settlements ($F = 0.60$; $p = 0.44$). There was no significant interaction between factors settlement type and region.

The level of the physical activity of the preschool children from rural settlements of the Central (Zagreb) macro-region (3.46) is significantly lower than the level of the physical activity of the preschool children from rural settlements of the Dalmatian (Split) macro-region (3.73; $p<0.05$).

Two-way ANOVA showed that sedentary behaviour is significantly different in children from the different types of settlements in Croatia ($F = 15.14$; $p<0.01$) and different macro-regions ($F=10.65$; $p<0.01$) (Table 2). There was no significant interaction between factors settlement type and region. Sedentary behaviour in the preschool children from the rural settlements of the Zagreb macro-region (145.54) and the rural settlements of the Eastern Croatian (Osijek) macro-region (150.69) are significantly higher than the sedentary behaviour of the preschool children from the urban (112.22; $p<0.01$) and the rural (118.51; $p<0.01$) settlements of the Northern Croatian coast (Rijeka) and the children from the Dalmatian urban settlements (112.68; $p<0.01$). There were no differences in sedentary behaviour within one specific macro-region. From all rural settlements, sedentary behaviour is the lowest on the Northern Croatian coast: significantly lower in Zagreb and the Eastern Croatian region ($p<0.05$).

Table 2. Differences in the level of physical activity and sedentary behaviour of preschool children in different Croatian macro-regions (MEAN±SD)

	Physical activity		Sedentary behaviour	
	Urban settlements	Rural settlements	Urban settlements	Rural settlements
Zagreb	3.54 ± 0.59	3.46 ± 0.61	132.69 ± 75.44	145.54 ± 69.21
Rijeka	3.59 ± 0.49	3.63 ± 0.54	112.22 ± 79.44*†	118.68 ± 74.00*†
Osijek	3.62 ± 0.56	3.66 ± 0.53	129.11 ± 58.18	150.69 ± 75.52
Split	3.65 ± 0.53	3.73 ± 0.54*	112.68 ± 55.89*†	134.00 ± 72.53

Note. * - significantly different from rural settlements in the Zagreb macro-region (p<0.01), † -significantly different from rural settlements in the Osijek macro-region (p<0.01).

Table 3. Differences in the level of physical activity and sedentary activities in preschool children in different age groups (MEAN±SD)

Age	Physical activity	Sedentary behaviour
3	3.66± 0.55	102.36± 60.15*†
4	3.61± 0.57	116.58± 68.71*†
5	3.54± 0.58	141.31± 74.32
6	3.56± 0.58	150.75± 77.22

Note. * - significantly different from five-year-old children at p<0.01, † - significantly different from six-year-old children at p<0.01.

Physical activity was not significantly different in preschool children of different ages (F = 2.61; p = 0.501), although average values show higher physical activity in younger compared to older children (Table 3). Significant differences were found in the amount of sedentary activities of preschool children of different age groups (F = 30.35; p<0.01). The three-year-olds (102.36; p<0.01) and the four-year-olds (116.58; p<0.01) spent significantly less time in sedentary activities compared to the five-year-olds (141.31) and the six-year-olds (150.75).

Furthermore, physical activity differed significantly with respect to gender (F = 43.57; p<0.01). Preschool boys (3.66±0,58) were more physically active than preschool girls (3.48±0,55; p<0.01). We also found significant differences in the sedentary behaviour of boys and girls (F = 18.65; p<0.01). Preschool boys spent more time in sedentary activities (138.92±77,82) than preschool girls did (123.67±64,83; p<0.01).

Discussion

This study reveals that children from the Central region, i.e., the continental area surrounding the capital city, are the least physically active, while the children from the rural settlements in the Dalmatian coastal region are the most active of all the preschoolers' in Croatia. Although there are differences in the level of physical activity in the children of the different geographical regions of Croatia, there are no differences in physical activity in children that could be attributed to the urban or rural setting in general. Physical activity is higher in boys compared to girls, and the tendency of lower physical activity is observable in older compared to younger preschool children.

The average physical activity results in children for almost all regions can be characterized as a high level of physical activity (results from 3.5 to 5): 53.8% of the total number of preschool children included in this research were categorized as highly active, meaning that they reached a satisfying level of physical activity. The only exception was the rural part of the Zagreb macro-region. The preschool children of this region were only moderately physically active (3.46) (results from 2.50 to 3.49). Observing the physical activity across the macro-regions (the sum of urban and rural settlements of a particular macro-region), it is evident that preschool children from the Dalmatian macro-region are the most active, while the preschool children from the Central macro-region are the least active. We can assume that various factors, such as different climates (continental vs Mediterranean), different lifestyles, and socioeconomic factors, are responsible for the differences in the physical activity in the children of different regions.

Furthermore, it is must be emphasized that preschool children from the coastal parts spend less time in sedentary activities, such as watching TV screens and playing computer games, compared to the preschool children from the continental parts. Bergman Markovic et al. (2011) found a greater prevalence of cardiovascular risk factors in adults of the continental region compared to the adults living in the Mediterranean parts of Croatia. They suggested that the likely explanation is in their different lifestyles. Having the long-term consequences of physical inactivity and increased sedentary behaviour in mind (Lavie et al., 2019), it is a worrying possibility that cardiovascular risk factors are region-specific.

Similar to previous studies examining gender differences in physical activity in children, preschool boys' physical activity levels were higher than those of preschool girls (Finn et al., 2002; Cardon et al., 2008; Sallis et al., 2000). A study conducted in the USA, using the same questionnaire (NPAQ), on a sample of children under 10 years of age showed that boys are more active (3.6 – high physical activity level) than girls (3.3 - medium level of physical activity) (Janz et al., 2005). These results are consistent with our study. Croatian boys have achieved a high physical activity level (3.66) compared to girls who have shown a medium level of physical activity (3.48).

This research also shows the differences in the duration of sedentary activities (watching TV and playing computer games) of the preschool children in the four Croatian regions. Those differences are the biggest in rural settlements. Sedentary behaviour is most prominent in the rural eastern continental region. In contrast, the preschool children from the urban settlements of both northern and southern coastal regions spend the least time in sedentary activities. On average, the preschool children from the rural settlements in the Eastern continental macro-region engage in sedentary behaviour for 2.5 hours per day, while the preschool children from the urban settlements in the two coastal regions engage in sedentary behaviour for less than two hours a day. Comparing different countries, Santaliestra-Pasias et al. (2013) were able to show regional as well as national differences. The data from their study (Santaliestra-Pasias et al., 2013) indicates that, compared to Italian, Estonian, Belgian, German, Swedish, Hungarian and Spanish children, Cypriot children spent the largest amount of time in sedentary activities such as watching television, DVDs, and other video content. Compared to the days of the week, there was a drastic increase in sedentary activities of this type during weekends. For this reason, particular attention should be given to the physical activity organized by both professionals and parents during the weekend periods.

The findings of this study indicate that children of different ages and genders differ significantly with respect to time spent in sedentary activities. It should be noted that the time spent in sedentary activities gradually increases with age, which is a very serious problem considering that the preschoolers have not yet reached the age at which a greater increase in sedentary behaviour is expected (school-age). Although more active than girls, boys have higher sedentary behaviour. This finding is in line with the abovementioned research of Santaliestra-Pasias et al. (2013), which showed that boys spend more time in sedentary activities than girls in the majority of the countries that were part of the study. In contrast to this, a US study of preschool children revealed that girls spend more time in sedentary activities (120 min) than boys do (108 min) (Janz et al., 2005). This shows that even if one child can be highly physically active for a while, he or she can then exhibit sedentary behaviour for an equal or longer amount of time playing computer games and watching television. The average duration of sedentary activities for all children in this research was 131.55 minutes, which exceeds given recommendations restricting daily sedentary behaviour to under one hour (WHO, 2019; Department of Health and Aging, 2010) as well as the more flexible recommendation of the American Academy of Pediatrics (2011) of two hours of sedentary behaviour. Considering that preschool children included in this research exceed all given recommendations, there is a practical need to focus on decreasing their sedentary behaviour. They should be helped, both by their parents and teachers, to better organize their free

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time so that it is spent in active play.

Previous research shows a decline in physical activity with the increasing age (Jurakic& Haimer, 2012; Sallis et al., 2000). Therefore, particular attention should be given to preschool girls, who are lagging in physical activity compared to preschool boys and have a greater decline in physical activity than boys with increasing age (Cragss et al., 2011). According to the World Health Organization (WHO, 2018), a similar percentage of Croatian boys (89%) and girls (87%) aged 8 meet the recommended daily level of physical activity, while this percentage decreases dramatically by the age of 15 to 25% of adequately active boys and 12% of adequately active girls (WHO, 2018).

The main limitation of this study is that physical activity and sedentary behaviour due to the large sample of children were estimated using questionnaires filled out by the parents of preschool children. Future studies on physical activity and sedentary behaviour in preschool children should be done using more objective means of measuring activity, such as accelerometers. Such devices would provide better information about physical activity and its intensity level (low, moderate, vigorous activity) than any questionnaire, especially one not assessed by a person about whose physical activity we are interested. Furthermore, children spent part of weekdays in kindergarten. Parents are not present during that time in daycare, and there is a possibility of under- or overestimation of physical activity assessment by parents.

Other socioeconomic and environmental factors could be attributed to differences in physical activity and sedentary behaviour in the Mediterranean and continental regions. Further analysis of these factors could provide additional information to specific research areas and should be addressed in future studies.

The lower level of physical activity and a higher sedentary behaviour in the continental regions in comparison to the coastal regions is an issue that should be specifically addressed. There is a need for a specific intervention strategy for improving physical activity in preschool institutions in the continental parts of Croatia. We believe that continental preschool institutions could benefit greatly from the experiences of the educational workers and kinesiologists from the coastal macro-regions. Such an exchange of good practices should be stimulated.

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ORIGINAL SCIENTIFIC PAPER

Analysis of Crossing Opportunities at the 2018 FIFA World Cup

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Abstract

The purpose of this study was to investigate open-play crosses at the 2018 FIFA World Cup tournament, with specific reference to the mechanism and match status of the crosses. Descriptive statistics (i.e., frequency counts and percentages) and chi-square tests of association were used to analyse the data. The study observed a total of 949 crosses, resulting in 20 goals scored (2.1%). Descriptive statistics highlighted that offensive teams had more goal-scoring attempts when they used counter-attacks (18.6%) compared to organized (18.2%) and direct (10.9%) attacks. A greater number of goal-scoring attempts were observed when teams used out-swinging crosses (17.4%) as opposed to in-swinging (15%) and straight (13.5%) crosses. There was a significant ($p < 0.05$) association between the type of attack and match status. Winning teams preferred to adopt a counter-attacking style of play; losing teams used more direct attacking strategies, and drawing teams utilized more organized attacks. Losing teams took the highest number of crosses from Zones 1 (61.1%) and 2 (56.7%) compared to other zones. These findings provide practical implications for football coaches to tailor match tactics to replicate crossing scenarios at international competitions.

Keywords: *cross outcome, match status, attacking, goal-scoring*

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Introduction

The majority of match analysis studies in association football have centred on the key game aspects of scoring and creating scoring opportunities (Pulling et al., 2018; Wright et al., 2011). Goal scoring is a key indicator of successful performance in football, as winning a game is dependent on scoring more goals than the opposition (Araya & Larkin, 2013). From an attacking perspective, delivering crosses from the wide areas of the pitch in the attacking third is a standard tactic for creating goal-scoring opportunities (Sarkar, 2018). In football terms, a cross is defined as the delivery of the ball from wide areas of the pitch into the opponent's 18-yard box (Hargreaves & Bate, 2010; Vecer, 2014). From open-play situations, this attacking tactical strategy has been found to contribute to 13% of goals scored at the 2006 and 2010 FIFA (Fédération Internationale de Football Association) World Cups and 28% at the 2002 FIFA World Cup (Mara et al., 2012; Smith & Lyons, 2017; Vecer, 2014). While crossing may contribute to goal-scoring opportunities, this area of performance analysis has received little

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attention among performance analysis researchers (Pulling et al., 2018).

To date, few published studies have formally investigated crossing at FIFA World Cups (Pulling et al., 2018). One seminal paper in the area investigated the mechanisms of crosses during the 1986 FIFA World Cup. Partridge and Franks (1989a; 1989b) analysed a total of 1,427 open-play crosses and concluded that crosses should be played first time, past the near post, behind defenders, without loft and hang time, and should not be delivered from around the corner flag. While this study provided key recommendations, the research was conducted over 30 years ago, and the game of football has since evolved with regards to playing style, team formations, rule changes and the use of technology (Kubayi & Larkin, 2019; Wallace & Norton, 2014). Therefore, there is a need to provide more contemporary analyses and suggestions for the use of crossing to create goal-scoring opportunities in football.

To extend the original analysis by Partridge and Franks (1989a; 1989b), Yamada and Hayashi (2015) examined 64 goal-scoring plays occurring from crosses in the 2010 FIFA World Cup and the 2012 European Football Championship tournaments. It was reported that early crosses were played between the penalty spot and the goal area; when defenders were organized, attacking players cut backcrosses around the penalty spot; and half of the crosses were delivered in front of the near post. Although the results provided some description of the types of crosses used in matches, a limitation of the research was that key performance variables, such as the time of crosses and defensive pressure, were not considered. This is an important consideration, as it will provide a more holistic description of crossing opportunities, which is lacking in the existing body of knowledge (Pulling et al., 2018).

Pulling et al. (2018) observed open-play crosses from all 64 games of the 2014 FIFA World Cup to address this gap. The results showed that a total of 1,332 crosses were played directly, resulting in 42 goals (3.2%), 56 attempts on target that did not result in a goal (4.2%), 80 attempts off-target (6.0%) and 1,154 of the crosses not leading to a goal-scoring opportunity (86.6%). Concerning the type of delivery, out-swinging crosses were the predominant type of cross (77.8%) compared to in-swinging (13.4%) and straight deliveries (8.9%). With regard to defensive pressure, the crosser was mostly under medium defensive pressure (i.e., a defender being 1.5–5 m away from the crosser) (48.0%) when delivering the cross. Finally, concerning the time of crosses, most were played during the last interval of the game (20.9%) (Pulling et al., 2018). While the findings indicate the type of crosses and when they occurred during a match, a shortcoming of the study is the limited acknowledgement of performance indicators such as the type of attack (i.e., direct attacks or counter-attacks) and the number of attacking and defensive players within the penalty box in relation to cross outcome.

While previous studies have provided descriptive understandings of crossing in men's football (Partridge & Franks, 1989a; 1989b; Yamada & Hayashi, 2015), more research is required to gain a holistic understanding of the mechanism of crossing for generating goal-scoring opportunities (Pulling et al., 2018). Furthermore, it is important to consider the potential relationship between crossing and match status (i.e., whether the crossing team is drawing, winning, or losing) to gain a complete perspective of the use of crossing as an attacking tactical strategy). Therefore, the purpose of the current study was to examine open-play crosses in the 2018 FIFA World Cup tournament, with specific reference to the mechanism and match status of the crosses. Football coaches can use the findings to inform coaching practice to replicate crossing scenarios relative to the game situation within the practice environment (Pulling et al., 2018).

Methods

Match Sample

All 64 matches played during the 2018 FIFA World Cup were analysed by the lead researcher using the Lince video analysis software (Gabin et al., 2012), with all crosses identified and coded. Crosses were included in the study if they were delivered into the 18-yard box and were delivered from Zones 1, 2, 3, 4 or 5 (Figures 1A and 1B). In accordance with previous crossing literature, set-piece and blocked crosses were excluded from the analysis (Pulling et al., 2018). As a result, a total of 949 open-play crosses were analysed for this study.

Observational instrument

An observational instrument adapted from previous studies (Casal et al., 2015; Kubayi & Larkin, 2019; Pulling et al., 2018; Pulling, 2013; Pulling, Robins & Rixon, 2013; Tenga et al., 2010a) was used in the current study. The instrument consists of the following 11 dimensions: 1) type of attack (i.e., organized attack, di-

Table 1. Operational Definitions of the Crossing Variables

Category and variables	Definition
Type of attack	
Organized attack	a) The possession starts by winning the ball in play or restarting the game. b) The progression towards the goal has a high number of non-penetrative and short passes. c) The ball tends to be moved across the width of the pitch rather than progressing deep towards the opposing goal, and the intention is to create disorder among the opposing team's players using a high number of passes and a relatively slow tempo (evaluated qualitatively). d) The defending team is in a balanced formation and has the opportunity to minimize any surprise attack.
Direct attack	(a) The possession starts by winning the ball in play or restarting the game. b) The progression towards the goal is based on one long pass from the defensive players to the forward players (evaluated qualitatively). c) The ball is moved deep up the pitch rather than across its width, and the intention is to move the ball directly towards the opposing goal area to have opportunities of finishing by using a reduced number or passes and a high tempo. d) The defending team is in a balanced formation and has the opportunity to minimize any surprise attack.
Counter-attack	a) The possession starts by winning the ball in play. b) The progression towards the goal attempts to utilize a degree of imbalance right from start to the end, with a high tempo. c) The ball is moved quickly up the pitch, and the intention is to exploit the spaces left by the opposing players when they were attacking. d) The defending team is in an unbalanced formation and does not have the opportunity to minimize a surprise attack.
Delivery type	
Out-swinging	The ball was kicked and moved in a curve away from the goal.

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Table 1. Operational Definitions of the Crossing Variables

Category and variables	Definition
In-swinging	The ball was kicked and moved in a curve towards the goal.
Straight	The ball was kicked with no curve.
Pitch side of delivery	
Right	The cross was delivered from the right side of the pitch.
Left	The cross was delivered from the left side of the pitch.
Defensive proximity to the crosser	
Low	There is no defensive player within 2 metres of the crosser.
Medium	A defender is between 1 and 2 metres away from the crosser.
High	A defender is less than 1 metres from the crosser.
Time of cross	
0–15 min	The cross was taken during the 0–15-minute period of the match.
16–30 min	The cross was taken during the 16–30-minute period of the match.
31 min–half-time	The cross was taken between 31 minutes and half-time.
46–60 min	The cross was taken during the 46–60-minute period of the match.
61–75 min	The cross was taken during the 61–75-minute period of the match.
76 min–full time	The cross was taken between 76 minutes and full time.
Extra-time	The cross was taken within the first or second period of extra time.
Number of attacking players in the 18-yard box	
Micro group	One or two attacking players located inside the 18-yard box when crosser kicks the ball.
Meso group	Three or four attacking players located inside the 18-yard box when crosser kicks the ball.
Macro group	Five or more attacking players located inside the 18-yard box when crosser kicks the ball.
Number of defensive players in the 18-yard box	
Micro group	Up to three defending players (excluding goalkeeper) located inside the 18-yard box when crosser kicks the ball.
Meso group	Between four and six defending players (excluding goalkeeper) located inside the 18-yard box when crosser kicks the ball.
Macro group	Seven or more defending players (excluding goalkeeper) located inside the 18-yard box when the crosser kicks the ball.
Cross outcome	
Goal	The ball went over the goal-line and into the net after an attacking player touched it. The referee awarded a goal.
Attempt on target excluding goals	Any goal attempt that was heading towards the goal but was saved by the goalkeeper or blocked by a defensive player.
Attempt off target	Any attempt by the attacking team that was not directed within the dimensions of the goal. An attempt that made contact with the crossbar or either of the posts was classified as an attempt off target.
Penalty	A player on the defending team committed a foul and the referee awarded a penalty.
Ball recycled out of the 18-yard box	The attacking team made contact with the ball, which led to the ball exiting the 18-yard box and possession being retained by the attacking team.
Unsuccessful attacking action	An attacking player contacts the ball after the cross but fails to control it, allowing the defenders an opportunity to recover it.
Defensive clearance – corner	A defensive outfield player made contact with the ball, and the referee awarded a corner kick.
Defensive clearance – throw-in	A defensive outfield player made contact with the ball, and the referee awarded a throw-in.
Defensive clearance	A defensive outfield player made contact with the ball, and it exited the 18-yard box.
No contact in the 18-yard box	The ball was not touched by any player and the ball exited the 18-yard box (includes goal kicks).
Goalkeeper gathers the ball	The goalkeeper comes and gathers/collects the ball (i.e., the cross bounces on the floor and then the goalkeeper collects the ball).
Goalkeeper catch	The goalkeeper gained possession of the ball by catching a cross.
Goalkeeper punch	The goalkeeper made contact with the ball by using a punching action.
Goalkeeper clearance	The goalkeeper made contact with the ball, and it exited the 18-yard box.
Match status	
Drawing	The score line for both teams was levelled (e.g., 0–0, 1–1).
Losing	The crossing team was trailing (e.g., 0–1, 1–2).
Winning	The crossing team was leading (e.g., 1–0, 2–1).

rect attack and counter-attack); 2) delivery type (i.e., out-swinging, in-swinging and straight); 3) side of the pitch (i.e., right and left); 4) defensive proximity to the crosser (i.e., low, medium and high); 5) time of cross (i.e., 0–15 min, 16–30 min, 31 min–half-time, 46–60 min, 61–75 min, 76 min–full time and extra-time); 6) number of attacking players in the 18-yard box (i.e., micro, meso and macro groups); 7) number of defensive players in the 18-yard box (i.e., micro, meso and macro groups); 8) zone of the crosser (see Figures 1A and 1B); 9) zone of the outcome (see Figures 1A and 1B); (0) the cross outcome (i.e., goal, attempt on target excluding goals, attempt off target, penalty, ball recycled out of the 18-yard box, unsuccessful attacking action, defensive clearance – corner, defensive clearance – throw-in, defensive clearance, no contact in the 18-yard box, goalkeeper gathers the ball, goalkeeper catch, goalkeeper punch and goalkeeper clearance); and 11) match status (i.e., team crossing was winning, drawing or losing). The operational definitions of these performance indicators are provided in Table 1.

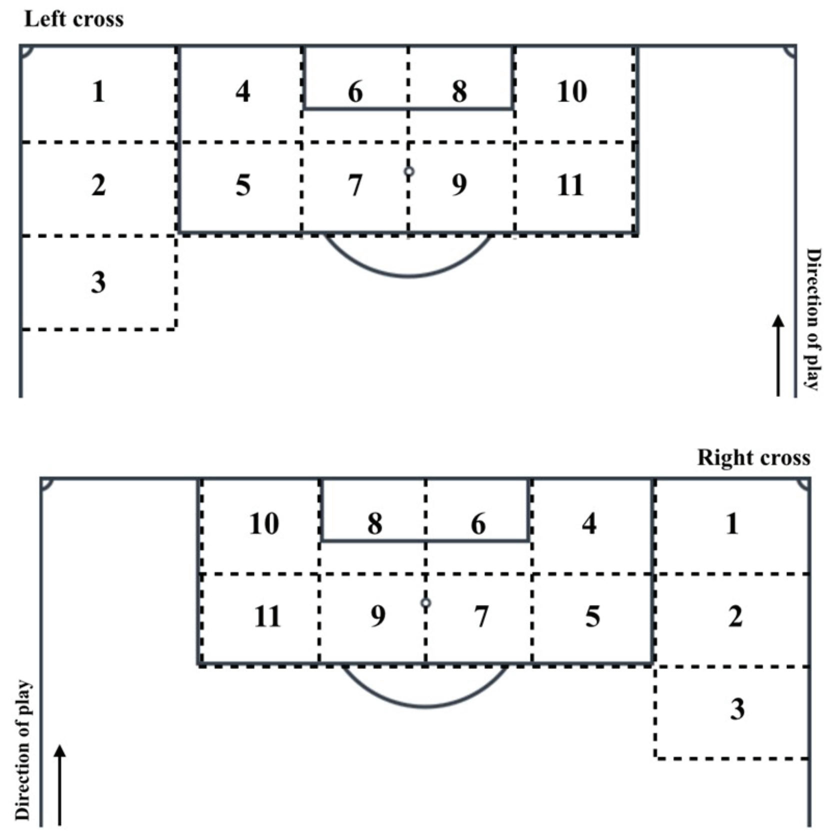

Figure 1. Zonal analysis for crosses delivered from the A) left and B) right side of the pitch

Reliability testing

Intra- and inter-observer reliability tests were examined using Cohen's kappa (κ) correlation coefficient. For intra-observer reliability, 121 crosses (i.e., 13% of total crosses) were selected and analysed on two occasions (separated by a two-week interval) by an independent football analyst. Kappa values > 0.80 were reported, showing the performance variables above the thresholds (Altman, 1991). Regarding inter-observer reliability, a second independent football analyst analysed the same number of crosses under similar conditions. Kappa values > 0.82 were observed for all performance indicators (Table 2).

Table 2. The Intra- and Inter-Rater Reliability Analysis (K) for Crossing Variables

Variable	Intra-observer Kappa value	Inter-observer Kappa value
Type of attack	0.91	0.84
Delivery type	0.90	0.88
Pitchside of delivery	1.00	1.00
Defensive proximity to the crosser	0.87	0.85
Time of cross	1.00	1.00
Number of attacking players in the 18-yard box	0.88	0.85
Number of defensive players in the 18-yard box	0.80	0.82
Zone of the crosser	0.84	0.87
Zone of the outcome	0.88	0.85
Cross outcome	0.86	0.84

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Statistical analysis

Frequency counts and percentages were used to analyse the crossing variables. Because some cells had expected counts of less than five, which undermined the assumption of a chi-square test (Thomas et al., 2015), the cross outcome variable was collapsed into four distinct categories: 1) goal-scoring attempts (i.e., goals, attempts on target excluding goals and attempts off-target); 2) attacking outcomes (i.e., ball recycled out of the 18-yard box, defensive clearance – corner, defensive clearance – throw-in and penalty); 3) defensive outcomes (i.e., defensive clearance, no contact in the 18-yard box and unsuccessful attacking action); and 4) goalkeeper actions (i.e., goalkeeper catch, goalkeeper gathers the ball and goalkeeper punch) (Pulling et al., 2018). Effect sizes were computed using Cramer's V (V) and interpreted as small (V = 0.10), medium (V = 0.30) or large (V ≥ 0.50) (Gravetter & Wallnau, 2007). A level of significance was set at 0.05. All statistical analyses were computed using SPSS version 26 (SPSS Inc., Chicago, IL, USA).

Results

Table 3 shows frequency counts and percentages of all crossing performance indicators. A total of 949 crosses were observed, resulting in 20 goals scored (2.1%). There were 51 attempts on target, excluding goals (5.4%) and 85 attempts off-target (9.0%). The most common cross outcome was a defensive clearance (40.5%). An organized attack was the main offensive strategy for crossing the ball (66.7%), followed by a direct attack (24.2%) and counter-attack (9.1%). The preferred delivery type was an out-swinging (69.1%) cross. When a cross was performed, defenders were positioned in a low (47.1%) or medium (40.6%) proximity to the crosser of the ball. The period in the match with the highest number of crosses was between the 76th minute and full time (17.4%). Most crosses were performed when a micro-number of attacking players (60.8%) or a meso-number of defensive players (60.5%) was in the 18-yard box. A greater number of crosses were taken from Zones 2 (31.6%) and 3 (36.2%), with the majority of crosses delivered to Zones 6 (26.8%) and 7 (21.4%).

Table 3. Frequency Counts and Percentage for Crossing Variables

Category and variable	Frequency (%)
Type of attack	
Organized attack	633 (66.7)
Direct attack	230 (24.2)
Counterattack	86 (9.1)
Delivery type	
Out-swinging	656 (69.1)
In-swinging	160 (16.9)
Straight	133 (14.0)
Pitchside of delivery	
Right	536 (56.5)
Left	413 (43.5)
Defensive proximity to the crosser	
Low	447 (47.1)
Medium	385 (40.6)
High	117 (12.3)
Time of cross	
0–15 min	140 (14.8)
16–30 min	128 (13.5)
31 min–half-time	144 (15.2)
46–60 min	160 (16.9)
61–75 min	153 (16.1)
76 min–full time	165 (17.4)
Extra-time	59 (6.2)
Number of attacking players in the 18-yard box	
Micro-group	577 (60.8)
Meso-group	342 (36.0)
Macro-group	30 (3.2)
Number of defensive players in the 18-yard box	
Micro-group	276 (29.1)
Meso-group	574 (60.5)
Macro-group	99 (10.4)
Zone of the crosser	
Zone 1	193 (20.3)

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Table 3. Frequency Counts and Percentage for Crossing Variables

Category and variable	Frequency (%)
Zone 2	300 (31.6)
Zone 3	344 (36.2)
Zone 4	72 (7.6)
Zone 5	40 (4.2)
Zone of the outcome	
Zone 4	16 (1.7)
Zone 5	30 (3.2)
Zone 6	254 (26.8)
Zone 7	203 (21.4)
Zone 8	178 (18.8)
Zone 9	90 (9.5)
Zone 10	29 (3.1)
Zone 11	13 (1.4)
No zone	136 (14.3)
Cross outcome	
Goal	20 (2.1)
Attempt on target excluding goals	51 (5.4)
Attempt off target	85 (9.0)
Penalty	2 (0.2)
Ball recycled out of the 18-yard box	20 (2.1)
Unsuccessful attacking action	27 (2.8)
Defensive clearance – corner	69 (7.3)
Defensive clearance – throw in	48 (5.1)
Defensive clearance	384 (40.5)
No contact in the 18-yard box	136 (14.3)
Goalkeeper gathers the ball	25 (2.6)
Goalkeeper catch	65 (6.8)
Goalkeeper punch	9 (0.9)
Goalkeeper clearance	8 (0.8)

Table 4 shows the crossing variables in relation to goal-scoring attempts, attacking and defensive outcomes, and goalkeeper actions. There was no significant association between the type of attack and cross outcomes ($\chi2 = 10.62$, $p = 0.09$, $V = 0.07$). However, the descriptive statistics indicated that teams had more goal-scoring attempts when they used counter-attacks (18.6%) compared to organized (18.2%) and direct (10.9%) attacks. In addition, there was no significant association between the type of delivery and cross outcome ($\chi2 = 7.15$, $p = 0.31$, $V = 0.08$), although the findings highlighted that there were a higher number of goal-scoring attempts when the teams used out-swinging crosses (17.4%) compared to in-swinging (15%) and straight (13.5%) crosses. In-swinging crosses resulted in more goalkeeper actions, while out-swinging crosses led to fewer goalkeeper actions. Crosses taken from Zone 5 (27.5%) produced the highest number of goal-scoring attempts, while those from Zone 3 (14%) yielded the lowest number of goal-scoring opportunities. Crosses delivered to Zone 5 (66.6%), Zone 7 (67%), Zone 9 (57.8%) and Zone 11 (61.5%) had higher defensive outcomes than other zones.

Table 4. Crossing Variables in Relation to Goal-Scoring Attempts, Attacking and Defensive Outcomes, and Goalkeeper Actions

Category and variable	Goal scoring attempts	Attacking outcomes	Defensive outcomes	Goalkeeper actions	X^2	Sig.	Cramer's *v*
Type of attack							
Organized attack	115 (18.2)	84 (13.3)	366 (57.8)	68 (10.7)	10.62	0.09	0.07
Direct attack	25 (10.9)	38 (16.5)	139 (60.4)	28 (12.2)			
Counterattack	16 (18.6)	17 (19.8)	42 (48.8)	11 (12.8)			
Delivery type							
Out-swinging	114 (17.4)	97 (14.8)	377 (57.5)	68 (10.3)	7.15	0.31	0.08

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Table 4. Crossing Variables in Relation to Goal-Scoring Attempts, Attacking and Defensive Outcomes, and Goalkeeper Actions

Category and variable	Goal scoring attempts	Attacking outcomes	Defensive outcomes	Goalkeeper actions	X^2	Sig.	Cramer's *v*
In-swinging	24 (15.0)	17 (10.6)	95 (59.4)	24 (15.0)			
Straight	18 (13.5)	25 (18.8)	75 (56.4)	15 (11.3)			
Pitchside of delivery							
Right	85 (15.9)	68 (12.7)	318 (59.3)	65 (12.1)	4.89	0.18	0.07
Left	71 (17.2)	71 (17.2)	229 (55.4)	42 (10.2)			
Defensive proximity to the crosser							
Low	73 (16.3)	67 (15.0)	260 (58.2)	47 (10.5)	5.52	0.48	0.06
Medium	69 (17.9)	49 (12.7)	220 (57.1)	47 (12.2)			
High	14 (12)	23 (19.7)	67 (57.3)	13 (11.1)			
Time of cross							
0–15 min	24 (17.1)	21 (15.0)	79 (56.4)	16 (11.4)	18.43	0.42	0.08
16–30 min	16 (12.5)	26 (20.3)	67 (52.3)	19 (14.8)			
31 min–half-time	20 (13.9)	14 (9.7)	94 (65.3)	16 (11.1)			
46–60 min	28 (17.5)	23 (14.4)	93 (58.1)	16 (10.0)			
61–75 min	25 (16.3)	28 (18.3)	80 (52.3)	20 (13.1)			
76 min–full time	32 (19.4)	17 (10.3)	101 (61.2)	15 (9.1)			
Extra-time	11 (18.6)	10 (16.9)	33 (55.9)	5 (8.5)			
Number of attacking players in the 18-yard box							
Micro-group	81 (14.0)	86 (14.9)	339 (58.8)	71 (12.3)	-	-	-
Meso-group	66 (19.3)	48 (14.0)	196 (57.3)	32 (9.4)			
Macro-group	9 (30.0)	5 (16.7)	12 (40.0)	4 (13.3)			
Number of defensive players in the 18-yard box							
Micro-group	41 (14.9)	39 (14.1)	156 (56.5)	40 (14.5)	5.88	0.45	0.06
Meso-group	96 (16.7)	84 (14.6)	339 (59.1)	55 (9.6)			
Macro-group	19 (19.2)	16 (16.2)	52 (52.5)	12 (12.1)			
Zone of the crosser							
Zone 1	28 (14.5)	34 (17.6)	113 (58.5)	18 (9.3)	-	-	-
Zone 2	51 (17.0)	40 (13.3)	176 (58.7)	33 (11.0)			
Zone 3	48 (14.0)	50 (14.5)	197 (57.3)	49 (14.2)			
Zone 4	18 (25.0)	11 (15.3)	37 (51.4)	6 (8.3)			
Zone 5	11 (27.5)	4 (10.0)	24 (60.0)	1 (2.5)			
Zone of the outcome							
Zone 4	2 (12.5)	6 (37.5)	8 (50.0)	0 (0)	-	-	-
Zone 5	2 (6.7)	6 (20.0)	20 (66.6)	2 (6.7)			
Zone 6	42 (16.5)	41 (16.1)	115 (45.3)	56 (22.1)			
Zone 7	33 (16.3)	32 (15.8)	136 (67.0)	2 (1.0)			
Zone 8	41 (23.0)	31 (17.4)	63 (35.4)	43 (24.2)			
Zone 9	25 (27.8)	12 (13.3)	52 (57.8)	1 (1.1)			
Zone 10	6 (20.7)	11 (37.9)	9 (31.0)	3 (10.4)			
Zone 11	5 (38.5)	0 (0)	8 (61.5)	0 (0)			
No zone	0 (0)	0 (0)	136 (100)	0 (0)			

There was a significant association between the type of attack and match status ($\chi2 = 31.72$, $p = 0.001$, $V = 0.13$). Winning teams preferred to adopt a counter-attacking style of play; losing teams used more direct attacking strategies; drawing teams adopted more organized attacks. A significant association was noted between the time of a cross and match status ($\chi2 = 135.95$, $p = 0.001$, $V = 0.27$). Losing teams delivered a greater number of crosses during the 0–15 min (85.7%) and 16–30 min (73.4%) periods of the game. There was a significant association between the number of defensive players in the 18-yard box and match status ($\chi2 = 15.90$, $p = 0.001$, $V = 0.09$). Teams had the highest number of defensive players in the 18-yard box when losing (65.6%). A significant association was found between the zone of the crosser and match status ($\chi2 = 37.20$, $p = 0.001$, $V = 0.14$), with losing teams delivering a greater number of crosses from Zones 1 (61.1%) and 2 (56.7%) compared to Zones 4 (47.2%) and 5 (45%) (Table 5).

Table 5. Crossing Variables in Relation to Match Status

Category and variable	Winning	Losing	Drawing	X^2	Sig.	Cramer's *v*
Type of attack				31.72	0.00	0.13
Organized attack	63 (9.9)	331 (52.3)	239 (37.8)			
Direct attack	34 (14.8)	137 (59.6)	59 (25.6)			
Counterattack	24 (27.9)	36 (41.9)	26 (30.2)			
Delivery type				4.80	0.30	0.05
Out-swinging	87 (13.3)	355 (54.1)	214 (32.6)			
In-swinging	16 (10.0)	88 (55.0)	56 (35.0)			
Straight	18 (13.5)	61 (45.9)	54 (40.6)			
Pitch side of delivery				0.22	0.90	0.01
Right	70 (13.1)	286 (53.3)	180 (33.6)			
Left	51 (12.3)	218 (52.8)	144 (34.9)			
Defensive proximity to the crosser				0.50	0.97	0.02
Low	56 (12.5)	234 (52.4)	157 (35.1)			
Medium	51 (13.2)	206 (53.5)	128 (33.3)			
High	14 (12.0)	64 (54.7)	39 (33.3)			
Time of cross				135.95	0.00	0.27
0–15 min	6 (4.3)	120 (85.7)	14 (10.0)			
16–30 min	11 (8.6)	94 (73.4)	23 (18.0)			
31 min–half-time	23 (16.0)	76 (52.8)	45 (31.2)			
46–60 min	23 (14.4)	82 (51.2)	55 (34.4)			
61–75 min	24 (15.7)	49 (32.0)	80 (52.3)			
76 min–full time	25 (15.1)	61 (37.0)	79 (47.9)			
Extra-time	9 (15.2)	22 (37.3)	28 (47.5)			
Number of attacking players in the 18-yard box				-	-	-
Micro-group	98 (17.0)	290 (50.3)	189 (32.7)			
Meso-group	21 (6.1)	199 (58.2)	122 (35.7)			
Macro-group	2 (6.7)	15 (50.0)	13 (43.3)			
Number of defensive players in the 18-yard box				15.90	0.00	0.09
Micro-group	49 (17.8)	129 (46.7)	98 (35.5)			
Meso-group	66 (11.5)	310 (54.0)	198 (34.5)			
Macro-group	6 (6.1)	65 (65.6)	28 (28.3)			
Zone of the crosser				37.20	0.00	0.14
Zone 1	22 (11.4)	118 (61.1)	53 (27.5)			
Zone 2	37 (12.3)	170 (56.7)	93 (31.0)			
Zone 3	34 (9.9)	164 (47.7)	146 (42.4)			
Zone 4	21 (21.2)	34 (47.2)	17 (23.6)			
Zone 5	7 (17.5)	18 (45.0)	15 (37.5)			
Zone of the outcome				-	-	-
Zone 4	9 (56.2)	1 (6.2)	6 (37.5)			
Zone 5	7 (23.3)	9 (30.0)	14 (46.7)			
Zone 6	93 (36.6)	46 (18.1)	115 (45.3)			
Zone 7	65 (32.0)	51 (25.1)	87 (42.9)			
Zone 8	70 (39.3)	39 (21.9)	69 (38.8)			
Zone 9	28 (31.1)	24 (26.7)	38 (42.2)			
Zone 10	8 (27.6)	7 (24.1)	14 (48.3)			
Zone 11	7 (53.8)	2 (15.4)	4 (30.8)			
No zone	40 (29.4)	37 (27.2)	59 (43.4)			

Discussion

The current study investigated crossing opportunities at the 2018 FIFA World Cup. A total of 949 crosses were observed, resulting in 20 goals (2.1%) scored. This statistic is lower than those in previously reported studies, in which 1,427 (2.7% goals) and 1,332 (3.2% goals) crosses were observed at

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the 1986 and 2018 FIFA World Cup tournaments, respectively (Pulling et al., 2018; Partridge & Franks, 1989a; 1989b). In addition, 5.4% of attempts on target did not result in a goal, and 9% of crosses led to off-target attempts. Surprisingly, despite the higher percentage of attempts at goal compared to the 2014 World Cup (Pulling et al., 2018), there was a low scoring rate at the 2018 World Cup. This result may suggest that football coaches are developing and implementing better defensive strategies to deal with crosses, or teams are implementing more of a possession-based and central attacking strategy. However, as it was not an aim of this paper to determine the reasons for the differences in crossing statistics between tournaments, this may be something for future research to consider.

The current study showed that more crosses were performed using an organized attack rather than direct attacks and counter-attacks. This finding suggests that teams may prefer to hold onto the ball rather than consistently play long balls into the box (Kubayi & Toriola, 2018). In relation to the type of delivery, the highest proportion of crosses were out-swinging deliveries as opposed to in-swinging and straight crosses. This result is expected, considering that players on the left side of the pitch would mainly use their left foot to cross the ball and vice versa (Pulling et al., 2018). Most crosses were performed while low or medium pressure was being applied to the player delivering the cross. Therefore, a practical recommendation for football coaches would be to develop training sessions that promote increased defensive pressure on the player crossing the ball. Doing so may channel the attacking player towards the corner flag or force them to play the ball backwards, thus reducing the number of crosses into the 18-yard area. Finally, a greater number of crosses were delivered into the box during the last interval of the game (i.e., 76th minute – full-time). This finding suggests that during the final period of the game, teams aim to play the ball into the box in an attempt to create a goal-scoring opportunity in order to obtain a positive result from the match (Kubayi, 2020).

While the findings indicated that more crosses were performed using an organized attack, in relation to creating goal-scoring opportunities, a higher percentage of goal-scoring attempts were achieved when teams adopted a counter-attacking strategy. This finding is consistent with previous literature, which reported that teams in the Norwegian professional league that used a counter-attacking strategy scored more goals than those that adopted more elaborate attacking strategies (Tenga et al., 2010b). An advantage of a counter-attacking style of play is that it quickly moves the ball to offensive zones and prevents defending teams from reorganizing (Kim et al., 2019). As a result, it may lead to more goal-scoring opportunities for the attacking team. Therefore, if coaches want to increase the goal-scoring opportunities for their team, they may want to consider adopting a more counter-attacking style of play.

When considering the type of delivery, out-swinging crosses produced more goal-scoring attempts than other types of crosses did. This result supports the findings of Casal et al. (2015), who identified that teams using out-swinging crosses had a higher number of shots on target than those using in-swinging crosses. Furthermore, in-swinging crosses resulted in more goalkeeper actions compared to out-swinging crosses. The current study also corroborates the findings of Pulling et al. (2018), who reported that in-swinging crosses promote more goalkeeper interventions, presumably due to the ball angling towards the goalkeeper during its flight, which may influence the goalkeeper's decision-making process in terms of coming out and claiming the ball. Conversely, out-swinging crosses may reduce the ability of the goalkeeper to intercept a ball or leave the goal line to claim it (Kubayi & Larkin, 2020; Link et al., 2016; Pulling et al., 2018), thereby giving the attacking players more time and space to direct the ball towards the goal (Casal et al., 2015).

In relation to the area on the pitch from which a cross was delivered, crosses from Zone 3 had the lowest number of goal-scoring attempts. A possible explanation for this finding could be that as this zone is the furthest from the goal; once the ball has been crossed, it is likely to travel a greater distance and for a greater duration of time, thus giving the defensive team a greater opportunity to position themselves to intercept the ball (Pulling et al., 2018). Interestingly, Zones 5, 7, 9 and 11 had a greater number of defensive outcomes than all other zones, which could be because it is easier for defenders to clear the ball out of the 18-yard box without conceding a throw-in or corner kick if the cross is delivered from within the 18-yard box, as the defenders may be positioned closer to the crosser and the intended target (i.e., they are in Zones 5, 7, 9 and 11) (Pulling et al., 2018).

A key aim of the current study was to understand the influence of match status in relation to crossing variables. Overall, the findings demonstrate that losing teams played more crosses than winning and drawing teams, which is clearly an attempt to create more goal-scoring opportunities and get back into the game. In addition, losing teams delivered a greater number of crosses during the 0–15 min and 16–30 min periods. This finding may indicate that when a team is losing early in a match, there may be a sense of urgency during these first two intervals of the game in order to avoid chasing the game towards the end.

Further, losing teams also delivered a greater number of crosses from Zones 1 and 2 compared to Zones 4 and 5, which may indicate that when teams are losing, they tend to get the ball into wider positions on the field to create goal-scoring opportunities. It should also be noted that when teams were losing, they adopted a more organized crossing attacking strategy. This finding further supports those of Bradley et al. (2014), who reported that when teams were behind, they increased their possession, suggesting that they preferred to control the game by dictating the play. Conversely, the current findings indicated that when teams were winning, they used a counter-attacking style of play in relation to the crosses they delivered. This result substantiates those of previous studies, showing that when teams are winning, they do not retain ball possession but seem to adopt more counter-attacking strategies (Lago, 2009; Lago & Martin, 2007).

The present study aimed to analyse open-play crosses at the 2018 FIFA World Cup competition, with reference to the cross mechanism and match status. Of the 949 crosses observed, a total of 20 goals (2.1%) were scored. The findings showed that teams had more goal-scoring attempts when they adopted a counter-attacking strategy in contrast to direct and organized attacks. Out-swinging crosses produced a greater number of goal-scoring attempts as opposed to in-swinging and straight crosses. Winning teams were found to use a more counter-attacking style of play, while losing teams attempted more crosses and adopted more organized attacking strategies. Overall, the current study explains how teams implemented crossing strategies at the 2018 FIFA World Cup. The results provide football coaches with recommendations to develop successful crossing strategies at international competitions.

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ORIGINAL SCIENTIFIC PAPER

Match Running Performance of Brazilian Professional Soccer Players according to Tournament Types

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Abstract

The present study aimed to report different level games in terms of their external game loads, using data collected from GPS performance indicators in Brazilian soccer teams. We used measures of 464 performances of professional soccer athletes during the National Tournament (NT=265), State Tournament (ST=89), National Cup (NC=44), and the International Tournament (IT=66). The performance analysis included the assessment of Total (meters) and Relative (meters/minutes) distances; running (>14km/h), and sprinting (>18km/h) distance; the number of sprints (>18km/h and >24km/h); accelerations (above three m/s2), deceleration (less than three m/s2) and jumps (>30 cm); Total and Relative load – per minute. There were differences (p<0.05) in terms of relative distance between NT and ST (102.2 ±9.5 vs. 98.1± 10.3) and between ST and NC (98.1± 10.3 vs. 103.4 ±9.6). In sprints >18km/h NT differed from ST (60.4 ±5.9 vs 52.7 ±19.9). In sprints >24km/h differences could be found between NT and ST (10.7 ±5.9 vs 8.7 ±5.4). In Total Load NT differed with respect to ST (908.6 ±141.5 vs. 852.7 ±138.5) In Relative Load differences were reported between NT and ST (10 ±1.2 vs. 9.3 ±1.4) and IT (10 ±1.2 vs. 9.4 ±1.4), and between ST and NC (9.3 ±1.4 vs. 10.0 ±1.4). Finally, concerning deceleration, NT differed when compared to ST (36.1 ±9.9 vs. 32 ±11) as well as ST differed from IT (32 ±11 vs. 37.5 ±9.7). The present results make it possible to create specific training games according to tournament level associated with the predominant activities performed during the competition.

Keywords: *external load, football, time motion, aerobic, anaerobic*

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Introduction

Soccer is a sport of intermittent nature, which mixes technical and tactical skills, high intensity actions such as sprinting, jumping and changes in direction with short rest periods, with players getting to travel between 9 to 14 km per match, in different speed bands (Dolci et al., 2020; Turner & Stewart, 2014)., In the last decades, physical demands have been significantly increasing (Bradley et al., 2016; Bush et al., 2015), par-

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alleling the interest of researchers and practitioners towards match fitness performance outcomes. The latter has, indeed, grown tremendously, in particular, using distance-based measures (e.g., distance traveled at different velocities) to improve physical conditioning strategies (Aquino et al., 2021; Hands & Janse de Jonge, 2020).

A large amount of research has been conducted to identify the major determinants underlying conditional or physical demands during a soccer match. These include the location (local or visiting) (Oliva-lozano et al., 2021), match status and goal difference (Buchheit et al., 2018), tactical systems adopted (Aquino et al., 2020), category (age-group) (Papaevangelou et al., 2012), division (Gomez-Piqueras et al., 2019), and ranking (Aquino et al., 2021), among others.

However, few studies have analyzed the differences in these demands between tournament types (state, national and international) (Andersson et al., 2010; Bradley et al., 2010), where, according to the existing literature, the tournament system (league or play-off) could have an impact, even though with contrasting findings being reported. One study that analyzed the external load of 100 and 10 female players during national/domestic and international tournaments, respectively (Bradley et al., 2010), found that players ran similar high intensity distances. On the contrary, another study (Andersson et al., 2010) found that female players ran distances at higher intensities when playing international versus domestic games.

Moreover, several studies have analyzed differences in performance outcomes according to the level (division) in leagues of different countries such as Germany (Hoppe et al., 2015), Italy (Rampinini et al., 2009), United Kingdom (Di Salvo et al., 2013), Spain (Gomez-Piqueras et al., 2019) and Brazil (Aquino et al., 2017), and have found different results according to the league, warranting the replication of this kind of analysis with the different leagues of the world.

Other studies have analyzed further factors that may influence external match load such as congested periods and have analyzed matches from different tournaments as a whole (Castellano et al., 2020; Gabbett et al., 2013), which could affect results by an increase in the variability of external load variables.

Knowledge of the external load differences between various types of tournaments is of paramount importance in that it could help coaches and technical staff plan the load of the competition micro-cycles according to the tournament in which players participate. Therefore, the present study aimed to assess different level games in terms of their external game loads, using data collected from GPS performance indicators in Brazilian soccer teams. We hypothesized that there is a significant difference in performance demands between games at different competitive levels.

Methods

Participants

464 performances of Brazilian professional soccer athletes (height: 1.81±0.29 cm; weight: 73.77±13.25kg; age: 23.8 ± 6.34 years-old; 56 attackers, 103 wingers, 195 midfields and 110 defenders) during the National Tournament (NT=265), called Brasileirão Série A, State Tournament (ST=89), called Carioca, National Cup (NC=44), called Copa do Brasil, and during an International Tournament (IT=66), called Copa Libertadores da América, were used in the present study. These performances were collected from professional athletes who competed in national, state, and international representative championships once per week and were regularly training (technical and tactical) 4-7 times a week during the evaluation period. All measures occurred between February and September 2018. Concerning inclusion criteria, we included complete data of players that showed all the results in each of the tests used in the present study, aged over 18 years, without cognitive alterations, without recent surgeries and without injuries and with more than two years in the professional soccer level. Exclusion criteria were the following: players who were unable to complete 75% of the game or who had limitations during the study, mainly for health reasons, duly certified by doctors. Also, the participants were instructed not to intake alcohol or drugs for at least 24 hours before the games and measures and were maintaining normal diets. Before proceeding with data collection, all participants attended a briefing meeting and signed an informed consent document to ensure the understanding of the testing parameters and the risks and benefits associated with the study. In addition, a letter of consent was sent and duly signed by the Brazilian's Club. This study was submitted to and approved by the Local Committee of Ethics in Research (protocol 051979/2017), following the rules of resolution of the National Health Council and according to the WMA Declaration of Helsinki.

Procedures and measures

During each trial, subjects wore a GPS device (Catapult Innovations, Scoresby, Australia) (Jennings et al., 2010). Performance analysis of professional soccer players were monitored using a portable 5-Hz GPS unit (Catapult, Melbourne, Australia) during games. The GPS device was positioned via an elasticized shoulder harness to sit between the scapulae of the bowler at the base of the cervical spine (Petersen et al., 2009). The GPS unit was activated and GPS satellite lock was established for at least 15 min before the player taking the field as per the manufacturer's recommendations (Petersen et al., 2009). After each session, the recorded information was downloaded using Caput Sprint software (Catapult Innovations, Melbourne, Australia) for analysis. Once downloaded, competition data was edited and split into two 45min halves (Abbott et al., 2018).

Only subjects completing more than 75% of the match were included within the analysis process. The mean number of satellites, and the horizontal dilution of position were recorded during data collection (Abbott et al., 2018). Performance analysis followed the standardized protocol (Abbott et al., 2018). Total distance (meters) - distance travelled during all the game; Relative distance (meters/minutes) - Total distance by minute; percentage of distance traveled movement speed and running (>14km/h), and sprinting (>18km/h) distance; number of sprints (>18km/h and >24km/h); maximum speed (km/h); number of accelerations (above 3 m/s2) and deceleration (less than 3 m/s2); jumps (with more than 30 cm), Explosive efforts - accelerations, deceleration and jumps frequency; Total Load - and Relative load – per minute were the performance indicators assessed during professional soccer games with ~90min of durations (Abbott et al., 2018). Total and relative (load/min) Loads were calculated using an established algorithm and considering forward, lateral, and upwards acceleration, and time in the PlayerTek system (Catapult Innovations, Melbourne, Australia).

Statistical Analysis

Descriptive statistics was presented as means and standard deviations. Data normal distribution was checked

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through the Kolmogorov-Smirnov test. Regarding inferential statistical analysis, repeated measures analysis of variance (ANOVA) with Bonferroni post-hoc tests were used to compare the total and relative time for each variable amongst groups. Partial Eta squared (η^2p) values were calculated to evaluate the ANOVA effect size. All analyses were performed utilizing SPSS software (version 20.0; SPSS, Inc., Chicago, IL, USA).

Results

The descriptive analysis of performance indicators of different soccer tournament levels with computed statistical inferences is shown in Table 1. There were differences ($p<0.05$) in terms of relative distance ($F=5.35$ and $\eta^2p=0.034$) between NT and ST (102.2 ±9.5 vs. 98.1± 10.3) and between ST and NC (98.1± 10.3 vs. 103.4 ±9.6). In runs >18km/h ($F=3.3$ and $\eta^2p=0.021$) differences could be reported between NT and ST (60.4 ±5.9 vs 52.7 ±19.9). In sprints >24km/h ($F=3.13$ and $\eta^2p=0.02$) NT differed with respect to ST (10.7 ±5.9 vs 8.7 ±5.4). In Total Load ($F=3.94$ and $\eta^2p=0.025$) NT differed from ST (908.6 ±141.5 vs. 852.7 ±138.5) In terms of Relative Load ($F=8.33$ and $\eta^2p=0.052$), differences could be found between NT and ST (10 ±1.2 vs. 9.3 ±1.4) and IT (10 ±1.2 vs. 9.4 ±1.4), and between ST and NC (9.3 ±1.4 vs. 10.0 ±1.4). Finally, deceleration ($F=4.63$ and $\eta^2p=0.029$) differed based on tournament, with differences recorded between NT and ST (36.1 ±9.9 vs. 32 ±11) and between ST and IT (32 ±11 vs. 37.5 ±9.7).

Table 1. Descriptive and inferential analysis of performance indicators by soccer tournament levels

Variable/groups		Mean	SD	F	Sig.	Pn2	NT	ST	NC	IT
	NT	9337.5	1281.0	1.39	.242	.009				
	ST	9032.4	1164.3							
Total Distance (m)	NC	9342.4	1205.0							
	IT	9210.7	1332.4							
	Total	9261.4	1261.7							
	NT	102.2	9.5	5.35	≤.001	.034		.005		
	ST	98.1	10.3				.005		.023	
RelativeDistance (m/min)	NC	103.4	9.6					.023		
	IT	99.2	11.2							
	Total	101.1	10.0							
	NT	19.4	5.2	.81	.485	.005				
	ST	18.6	5.2							
% of sprints>14km/h	NC	18.4	5.6							
	IT	19.1	4.8							
	Total	19.1	5.2							
	NT	8.6	2.9	1.95	.120	.013				
	ST	7.9	2.8							
% of sprints>18km/h	NC	7.8	2.8							
	IT	8.3	2.8							
	Total	8.3	2.9							
	NT	60.4	20.1	3.30	.020	.021		.011		
	ST	52.7	19.9				.011			
sprints>18km/h (frequency)	NC	57.6	20.4							
	IT	58.7	20.3							
	Total	58.4	20.3							
	NT	812.2	314.0	2.40	.067	.015				
	ST	722.2	294.1							
Total Distance (m) > 18km/h	NC	735.3	275.4							
	IT	770.3	292.5							
	Total	781.7	305.2							
	NT	10.7	5.9	3.13	.025	.020		.028		
	ST	8.7	5.4				.028			
Sprints>24km/h (frequency)	NC	9.1	5.5							
	IT	10.0	6.3							
	Total	10.1	5.9							

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Variable/groups		Mean	SD	F	Sig.	Pn2	NT	ST	NC	IT
Total Distance (m) > 24km/h	NT	158.8	97.3	1.96	.119	.013				
	ST	133.5	91.5							
	NC	137.4	88.1							
	IT	143.6	103.9							
	Total	149.8	96.7							
Maximum speed (km/h)	NT	29.8	2.0	.96	.408	.006				
	ST	29.4	2.3							
	NC	29.9	2.4							
	IT	29.7	2.3							
	Total	29.7	2.1							
Total Load (Score)	NT	908.6	141.5	3.94	.009	.025		.008		
	ST	852.7	138.5				.008			
	NC	900.9	128.6							
	IT	874.1	149.2							
	Total	892.2	142.3							
Relative Load (score/ min)	NT	10.0	1.2	8.33	≤.001	.052		≤.001		.019
	ST	9.3	1.4				≤.001		.017	
	NC	10.0	1.4					.017		
	IT	9.4	1.4				.019			
	Total	9.8	1.3							
Acceleration (frequency)	NT	31.5	9.2	2.22	.085	.014				
	ST	28.9	7.6							
	NC	31.9	9.4							
	IT	31.8	9.8							
	Total	31.1	9.0							
Deceleration (frequency)	NT	36.1	9.9	4.63	.003	.029		.008		
	ST	32.0	11.0				.008			.006
	NC	36.0	11.7							
	IT	37.5	9.7					.006		
	Total	35.5	10.4							
Jumps (frequency)	NT	12.0	5.1	3.25	.022	.021				
	ST	13.1	6.2							
	NC	13.9	4.9							
	IT	13.8	5.6							
	Total	12.6	5.4							
Explosive efforts (frequency)	NT	124.9	36.0	2.44	.063	.016				
	ST	120.6	37.7							
	NC	133.0	37.8							
	IT	134.8	39.6							
	Total	126.3	37.2							
Game time (min)	NT	91.5	10.2	.62	.601	.004				
	ST	92.5	9.1							
	NC	90.7	10.1							
	IT	92.8	9.1							
	Total	91.8	9.8							

Discussion

The main results indicated higher relative displacement of National Tournament and National Cup than State Level, as National Tournament presented higher total, and relative load, deceleration, frequency of efforts above 18km/h and 24km/h than State Level. In addition, international soccer games presented higher deceleration and relative load than state-level games.

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The results reported in the present study are consistent with the findings of other studies. For instance, Andersson et al. (2010) found that professional players ran longer distances at high intensity during international matches, mainly because increasing the level of competition may result in increasing the workload of the athletes (Mohr et al., 2008). Therefore, in NT, teams with better physical condition are more likely to participate, and their game strategies are characterized by imposing greater intensity. In this case, the top-ranked teams in the state championship are the ones that qualify for the national championship, and it has been found that a higher-ranked team runs greater distances in accelerations (>3m/s2) (Aquino et al., 2021).

However, in contrast to our results, Bradley et al. (2010) found no differences in match displacement between international and domestic matches, but this could be due to several reasons. First, the sample was not paired; 100 domestics vs. ten international league subjects were analysed. Moreover, factors such as playing position (Andersson et al., 2010) or intra-subject variability could affect the results.

Rienzi et al. (2000) compared the work profiles of professional players in matches for their national team (South America) and domestic league matches (England). They found that domestic league players ran a greater total distance than international players, but this could be because they compared different players, and their position could have affected the results, as well as the sample was not paired as in the Bradley et al.'s study (2010).

A limitation should be recognized concerning the GPS sampling frequency, which shows good reliability up to actions below 20 km/h (Johnston et al., 2013). As such, actions above this threshold could exhibit more noise or variability between matches. Also, the position of the players and their intra-individual variability could influence the results (Altmann et al., 2021). Therefore, it is suggested that future research should consider these factors when performing the analyses. On the other hand, future research that analyses factors influencing external match load should consider separately analysing matches from different tournaments.

From a practical point of view, knowledge of the differences in match performance could be useful to know the post-match recovery; in this case, players had a lower frequency of decelerations and runs >18km/h during ST and associations of this variable with post-match Creatine Kinase levels have been found (Freire et al., 2020).

In summary, the external load of Brazilian team players varies in terms of some variables depending on the type of tournament. The present results make it possible to create specific training games according to tournament level associated with the predominant activities performed during the competition. Based on the present study, coaches and fitness trainers of Brazilian teams could adapt their training programs according to the requirement of each tournament level. These findings should be used with caution when considering competitions in other countries, therefore future research should analyse competitions taking into account the country in which they take place.

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ORIGINAL SCIENTIFIC PAPER

Repeated Sprint Ability of Youth Football Players in the Same Age Category According to Playing Position and Competition Level

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Abstract

This study aims to examine repeated sprint performances of young soccer players in the same age category according to competition level and playing positions. 67 young soccer players in the U16 age category and from 4 different teams competing in two different competition levels participated voluntarily in this study. The participants performed the Bangsbo Sprint Test adapted by Wragg (7×34,2 m with 25-second recovery) to determine repeated sprint performance. The test variables were best sprint time, mean sprint time, and the fatigue index. The best sprint time and mean sprint time results varied according to competition level ($p<0,05$) but the fatigue index did not differentiate according to competition level ($p>0,05$). It is also determined that at a high competition level players have revealed better-repeated sprint performance. When examined the data in terms of game position, best sprint time and mean time values have varied ($p<0,05$) but the fatigue index did not have significant differences ($p>0,05$). Considering the data according to game positions, forwards, full-backs and wingers showed higher performance than central midfielders, central defenders, and goalkeepers. Consequently, our results suggest that performance in repeated-sprint the best sprint values and mean sprint values belonging to repeated performances of youth players from the same age category differ according to competition levels and game positions, whereas the fatigue index does not differ.

Keywords: *repeated sprint ability, age category, competition level, playing position*

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Introduction

The workload rate of the football player during matches' ranges from low-level activities such as walking and jogging to high-intensity activities such as sprinting (Abrantes et al., 2004). In addition, today's football has become faster than in the past in terms of the speed of the ball passing from player to player and the player's movements (Jeffreys & Bate, 2015). Football match analysis studies showed that football requires the ability to perform repeated maximal or submaximal short-term actions with short recovery periods (Bravo et al., 2008). Due to the repetitive occurrence of sprints before sufficient recovery time during football matches, successive sprint performance deteriorates. Thus, one of the most important conditioning features of an athlete in team sports is the ability to perform sprint runs with short recovery in-

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tervals, which is called repeated sprint ability (Mujika et al., 2009; Spencer et al., 2006; Spencer et al., 2004). Repeated sprint ability is an important team sport component that requires athletes to produce irregularly split maximal and submaximal short sprints with incomplete recovery periods throughout the match (Barbero-Álvarez et al., 2013). Therefore, the ability to repeat multiple sprints is important for the physical performance of the football player, and accordingly, the use of repeated sprint exercises and tests is increasing day by day (Impellizzeri et al., 2008).

Even though the sprint distance in the football game is less than 10% of the total distance covered, it is one of the most important performance variables. The result of a football match may depend on a player performing a sprint faster than their opponent (Abrantes et al., 2004). The result of a football match may depend on a player performing a sprint faster than their opponent. Speed in football can differ not only according to other sports but also according to the playing positions, and speed is a valuable performance component in football for every position except the goalkeeper (Gatz, 2009). Past researches stated that in team sports, sprints occur repeatedly before the recovery period is complete, and therefore sprint performance may be impaired (Falk & Dotan, 2006). In addition, it has been reported that repeated sprint performances of young athletes differ from adults due to shorter physiological recovery times after repeated sprint runs (Abrantes et al., 2004; Mendez-Villanueva et al., 2011; Mujika et al., 2009). In addition, in the studies conducted with simultaneous athlete tracking systems, it is stated that the performance and frequency of repetitive sprints in match activity vary according to age and playing position (Buchheit et al., 2010). However, there are very limited studies examining the repeated sprint performances of young football players in the same age category according to their playing positions and competition level.

Every year, millions of young football players in different parts of the world participate in the development programs of football clubs. Determining the level of important performance components according to the positions, and competition levels of young football players are very important for talent selection, evaluation of physical fitness, and developing long-term training for their development. Therefore, this research aims to examine the repeated sprint ability performances of young football players in the U16 age group according to their competition level and their playing positions.

Methods

Subjects

A total of 67 youth football players (age= 15.6±0.38 years; weight= 62.18±7.45 kg; height= 173.22±6.38 cm) playing football in the U16 age category of 4 teams (2 professional and 2 amateur) participated in the study voluntarily. 31 of these athletes play in the local amateur leagues and 37 of them play football in the development league, which is a higher league. Written informed consent was obtained from the players and their parents. In the interviews with the team leaders, it was determined that all of the athletes train 4-5 times a week and for 70-100 minutes.

Study design

All measurements of the research were taken during the competition period. 4 different measurement days were determined for 4 different teams. The repeated sprint test was applied on the synthetic grass and at least 2 days after the official competitions, while the athletes were recovered. All performance tests were performed in an outdoor facility maintained at standard environmental conditions. The tests were conducted during the day between 15:00 and 17:00. Height and weight measurements were taken between 10:00 and 11:00 in the morning. Since all the teams played almost all of their matches on synthetic grass, synthetic turf was chosen as the testing ground. Attention was paid to the fact that the athletes followed the same diet in their meals before the tests. This study was approved in advance by Gazi University Ethics Committee (Approval number: 77082166-604.01.02). Each participant voluntarily provided written informed consent before participating.

Repeated sprint test

The Bangsbo Sprint Test adapted by Wragg et al. was used to determine the repeated sprint ability performances of the participants. The Bangsbo Sprint Test protocol consists of 7 maximal sprints of 34.2 m each. The recovery between sprints is active and the athlete has 40 m to return to the start from the finish line and 25 seconds to run this distance at a slow pace (Pasquarelli et al., 2010). Since there is no generally accepted repetitive sprint test suitable for the intermittent nature of the football game, it is very difficult to determine the validity of these tests. However,

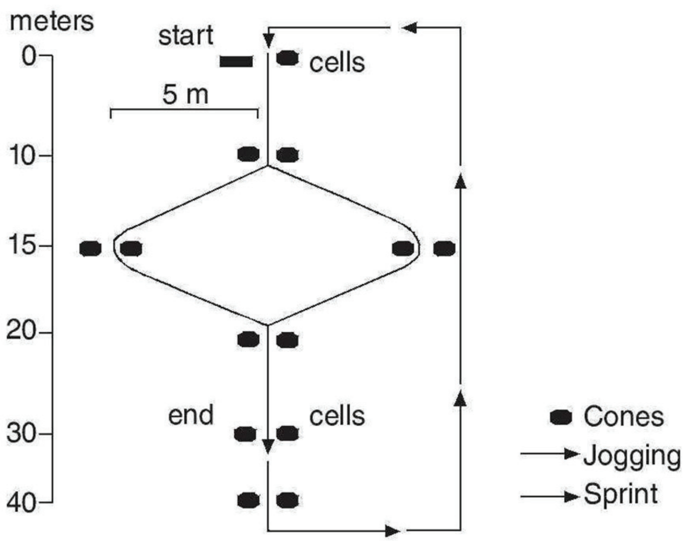

Figure 1. Schematics of Bansgsbo sprint test adapted by Wragg et al. (Pasquarelli et al., 2010)

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the 7×34.2 m deflection sprint test is considered a valid test. The 7×34.2 m change-of-direction sprint test was reliable because the coefficient of variation was 1.8% and it was in the 95% confidence interval (Wragg et al., 2000).

Before the test started, all participants performed a 20-minute warm-up that included general and test-specific activities. During the general warm-up part, the athletes performed low-intensity forward, sideways, and backward running, acceleration runs, skipping and hopping exercises, and jumps at increasing intensity. In the sprint part of the warm-up, after the participants did 2 20 m sprints including passive rest, 1 sprint was made to gain predisposition on the test area. After each sprint during the test, the recovery section, which lasted 25 seconds and included 40 m low tempo running, was carefully followed and feedback was given to each of the athletes about the remaining time in the 10th and 20th seconds of the recovery time. During the test, the athletes were verbally encouraged. Each 7 sprint time was recorded in seconds by the photocells located at the start and finish lines. The best sprint time, average sprint time, and fatigue index parameters were calculated as a result of the repeated sprint test.

Statistical analyses

IBM SPSS Statistics 22.0 package program was used in the analysis of the obtained data. The normality test of the data was analyzed with the Shapiro-Wilk test. Non-parametric analysis methods were used because the measurement data were not suitable for normal distribution. Mann Whitney U test was used to compare the best sprint and average sprint grades and fatigue index values according to competition levels, and the Kruskal Wallis H test was used to compare according to playing positions.

Results

As shown in Table 1. the best sprint and mean sprint times of young football players differ significantly according to the competition level ($p<0.05$), while the fatigue indexes do not differ significantly according to the competition levels ($p>0.05$). Development League players have better performances in all of the different sprint times (Table 1).

Table 1. Comparison of the Best Sprint, Mean Sprint, and Fatigue İndex Values of the Players According to Competition Level

Measures	Competition levels	N	X	SS	MR	U	P
Best sprint time	Devolopment league	35	6,31	0,253	27,29	325,0	0,003
	Local amateur league	32	6,46	0,210	41,34		
Mean sprint time	Devolopment league	35	6,49	0,229	26,77	307,0	0,001
	Local amateur league	32	6,65	0,203	41,91		
Fatigue index	Devolopment league	35	3,33	1,499	35,67	501,5	0,463
	Local amateur league	32	3,06	0,916	32,17		

As shown in Table 2, the best sprint, mean sprint times of the players differ significantly according to their playing positions ($p<0.05$). It was determined that the fatigue index data did not show a significant difference ($p>0.05$). The differences in the best sprint times are due to the times of the full backs and forward players being better than the centre backs, centre midfielders, and goalkeepers, while the central midfielders are better than the centre backs. The differences in the average sprint times are due to times of the full backs, wingers and forward players are better than the centre backs, centre midfielders and goalkeepers.

Table 2. Comparison of the Best Sprint, Mean Sprint, and Fatigue İndex Values of the Players According to Playing Positions

Measures	Playing positions	N	X	SS	MR	x2	P
Best sprint time	Full back	9	6,24	0,167	22,17	20,67	0,001
	Centre back	11	6,56	0,197	48,36		
	Winger	11	6,33	0,240	30,32		
	Centre midfielder	17	6,47	0,239	40,94		
	Forward	13	6,20	0,138	19,46		
	Goalkeeper	6	6,52	0,269	44,00		
Mean sprint time	Full back	9	6,43	0,168	22,39	24,97	0,000
	Centre back	11	6,72	0,203	47,14		
	Winger	11	6,42	0,124	22,73		
	Centre midfielder	17	6,70	0,226	44,65		
	Forward	13	6,41	0,128	21,04		
	Goalkeeper	6	6,72	0,240	45,92		
Fatigue index	Full back	9	3,22	1,140	34,89	8,4	0,136
	Centre back	11	2,39	0,954	20,77		
	Winger	11	2,98	1,589	30,14		
	Centre midfielder	17	3,69	1,386	40,76		
	Forward	13	3,46	1,013	38,92		
	Goalkeeper	6	3,10	0,788	34,17		

Discussion

In this study, we examined the differences in repeated sprint ability performances' of young football players in the same age category (U16) according to competition level and playing positions. The main findings of the study showed that repeated sprint performances' of young football players differ according to competition level and playing positions, the fatigue index does not differ.

Although no research in the literature examined the repeated sprint performance of young football players in the same age according to the competition level, the studies conducted on adults and examining the repetitive sprint ability according to the competition level are in line with the results of this study. Rampinini et al. (2009) examined the repeated sprint abilities of 12 professional and 11 amateur football players playing at different standards and the relationship of this ability with factors such as intermittent running test, oxygen consumption, and maximal oxygen consumption. As a result, they determined that the repeated sprint ability and the responses of this ability to various physiological factors differ between professional and amateur football players. Abrantes et al. (2004) applied the Bangsbo sprint test to 146 football players playing in different competition levels and different age categories in their study and evaluated the repeated sprint ability performances of football players in three different competition levels. As a result of the study, National 1st League (top-level) players showed higher repeated sprint performance than players playing in other leagues. In addition, Aziz et al. (2008) examined the validity of the repeated sprint ability test between position and competition level in football players and determined that repeated sprint ability was superior in teams with high competition levels. In a systematic review that investigated measurement properties and feasibility of a repeated sprint ability test, the authors reported that repeated sprint performance can discriminate soccer players of playing positions (goalkeepers and outfields), competition levels (professional, amateur, and semi-professional) (Lopes-Silva et al., 2019). One of the important reasons why the performance of repeated sprint ability differs according to competition level in young football players is because the quality of training differs according to the competition level. In this study, players at two different competition levels were examined. Especially since the Development League has a longer league period than the local amateur leagues, young football players can train for longer periods. It is thought that this situation contributes more to the physical development of young football players and therefore to their repetitive sprinting abilities compared to players at lower league levels.

In the past studies that examined the repeated sprint performance according to the playing positions, the researchers stated variable results. In one study of 85 adult amateur football players, in which repeated sprint performance and fatigue index were examined according to player positions, no significant relationship was found between playing positions, contrary to our study (Kaplan, 2010). Similarly, Lockie et al. (2019) examined18 adult football players and reported that repeated sprint performance did not differ according to playing positions. However, in these studies, position diversification was not as detailed as in this research (defenders, midfielders, and forwards). The progressive and changing tactical structure of the football game requires a more detailed examination of the players in terms of playing position. For example, as in our research, center-backs and full-backs showed different performance characteristics among defenders. In another study, Aziz et al. (2008) stated that forwards have higher repeated sprint ability performance compared to defenders and midfielders. Especially in today's football, which is played faster than in the past, the sprinting skills of the forward, full-backs, and winger players should be better than the players in other positions. Midfielders and central defenders, on the other hand, cannot find enough space for long-distance sprint runs due to their duties and positions on the field.

The results from this study showed that the fatigue index does not differ significantly according to the competition level and game positions. Although it was stated in the past studies that performance variables such as best sprint and average sprint provided sufficient absolute and relative reliability related to repeated sprint performance, low values were reported regarding the reliability of the fatigue index (CV: 14.4-52.0%) (Glaister et al., 2008; Lopes-Silva et al., 2019). Researchers stated that this is due to the use of different formulas to calculate fatigue in repeated sprint tests. For this reason, the use of the fatigue index is a situation that should be questioned due to the lack of reliability (Oliver, 2009).

In conclusion, repeated sprint performance also increases in direct proportion to the fitness levels of the players in leagues with high training quality and frequency. By the changing needs and tactical structure of football, repeated sprint ability also varies between playing positions. Coaches and football professionals can use repetitive sprint ability data as one of the key indicators in talent selection, creating a long-term training program and in the distribution of tasks according to physical characteristics in the football team. Future longitudinal studies with large samples as different age categories, and competition levels are necessary in order to confirm these results.

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ORIGINAL SCIENTIFIC PAPER

An Examination of Loading Profiles for Youth Athletes Performing the Hang Power Clean

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Abstract

Weightlifting derivatives have become an increasingly popular form of resistance training among youth athletes over the past decade. This study aimed to examine the loading profiles of youth athletes during the hang power clean to determine optimal loading parameters for force, power, rate of force development, and barbell velocity. Sixteen male youth athletes (Age: 16.94 ± 0.97 years; Height: 180.08 ± 8.14 cm; Body mass: 81.06 ± 15.04 kg; Hang Clean 1RM 70.17 ± 14.41 kg) performed three repetitions of the hang power clean at 10% intervals ranging from 30-90% of their one-repetition maximum (1RM). One-way repeated measures ANONAs revealed that external load had a significant effect on the peak and average of all variables examined ($p < 0.05$). Most notably, peak power was maximized at 70% 1RM which was not significantly different 60-90% 1RM. Peak rate of force development was maximized at 90% 1RM, though it was not significantly greater than 50-90%1RM. Conversely peak barbell velocity was maximized at 30% 1RM which was significantly greater than 50-90% 1RM. While the results for power are similar to that of older, stronger athletes, the youth population in this study maximized barbell velocity and rate of force development at different external loads compared to more developed athletes. These results seem to suggest that youth athletes need to achieve a higher level of strength before they are capable of training with high relative external loads while maintaining high barbell velocities.

Keywords: *youth, loading profiles, force-velocity, power, hang power clean*

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Introduction

It is imperative that competitive athletes produce large forces in relatively small timeframes during running, jumping, and cutting tasks (Channel & Barfield, 2008; McQuilliam et al., 2020; Meylan et al., 2015). To maximize this ability, athletes utilize resistance training exercises that produce maximal force in short time durations, thus enhancing their force-velocity profile (Morrissey et al., 1995). Weightlifting exercises and their derivatives have been advocated as an effective way to enhance the force-velocity profiles of various athletes (Suchomel et al., 2017; Suchomel et al., 2015). However, the force-velocity characteristics of a given training exercise depend on several variables, one of which is external load (Suchomel et al., 2017).

External load is a commonly modified variable in resistance training programs and is partially responsible for dic-

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tating the location of a specific exercise on the force-velocity curve (Suchomel et al., 2017). Loading profiles provide insight into the athletes' ability to accelerate a given load and achieve high power, barbell velocity, and force outputs (Meylan et al., 2015; Sheppard et al., 2008). The influence external load exhibits over the force-velocity characteristics of a training exercise makes it is necessary to further investigate the loading profiles associated with power, barbell velocity, force, and rate of force development (RFD) (Flores et al., 2007; Soriano et al., 2015). Coaches can use information from loading profiles to determine which external loads maximize one of the aforementioned variables along the force-velocity spectrum for a given exercise.

The hang power clean (HPC), has been widely studied to determine the loading parameters to optimize a variety of force-velocity variables. In professional rugby players, it was found external loads of 90% 1RM optimized peak force and peak RFD, while lighter external loads of 80% 1RM and 50% 1RM optimized peak power and peak velocity, respectively (Kilduff et al., 2007). In nonprofessional athletes and recreationally trained men with power clean experience, these numbers seemingly vary where peak power was maximized between 65-80% of 1RM, peak force between 80-90% of 1RM, peak RFD between 30-60% of 1RM, and peak velocity between 30-60% of 1RM (Kawamori et al., 2005; Suchomel et al., 2014A; Suchomel et al., 2014B). The wide ranging loading profiles for these studies have been attributed to variation in strength levels and training statuses of the athletes or participants. Several studies have suggested that stronger, more well trained athletes utilize higher relative external loads to maximize these common variables (Angel 1975, Kawamori et al., 2005; Stone et al., 2003), while some have noted that weaker, less trained athletes maximized one or more of these variables at higher relative loads compared to their well-trained counterparts (Baker et al., 2001).

Several studies have advocated for the use of the weightlifting exercises and their derivatives in adolescent populations to train athletes' strength-power characteristics (Channel & Barfield, 2008; Scherfenber & Burns, 2013). In fact, many strength coaches regard these lifts as staples of their training programs (Duehring et al., 2009), and resistance training is widely accepted as a safe and effective method for increasing muscular strength and power in adolescent populations (McQuilliam et al., 2020; Myers et al., 2017). Despite this, there has been a lack of investigation regarding the power, force, barbell velocity, and RFD loading profiles for youth athletes. Therefore, the purpose of this study was to examine the loading profiles of peak and mean power, force, barbell velocity, and RFD for youth athletes performing the HPC to determine the optimal loading parameters for these variables.

Methods

Participants

A power analysis conducted using G*Power (version 3.1.9.7, Kiel, Germany) with an effect size set at 0.3, an alpha level of 0.05, and a power of 0.80 determined a minimum number of twelve participants was required for the study (Faul et al., 2007). Sixteen high school male athletes (Age: 16.94 ± 0.97 years; Height: 180.08 ± 8.14 cm; Body mass: 81.06 ± 15.04 kg; Hang Clean 1RM 70.17 ± 14.41 kg; Relative Strength (HPC 1RM/Body Mass): 0.87 ± 0.15) were recruited from local private high schools to participate in the study. All athletes were required to compete in at least one power-based sport during the school year and had actively engaged in a structured resistance training program under the supervision of a Certified Strength and Conditioning Specialist for at least four weeks prior to testing. Sports represented included American football, tennis, wrestling, basketball, lacrosse, and track and field (sprints and throws). There were several multiport athletes included in the study and all participated in structured resistance training during the school year as part of their school curriculum. Athletes currently participating in a rehabilitation program excluded from participation. All participants and their parents/legal guardians (when necessary) were informed of the benefits and risks of participation and signed an informed consent document as approved by the University's Institutional Review Board.

Procedures

Participants attended three testing sessions spaced a minimum of 48 hours apart and participants were asked to refrain strenuous exercise 24 hours prior to testing. During the first session body mass was determined using a digital scale (Tanita Worldwide, Model BF 522, Arlington Heights, Illinois) to the nearest 0.1 kg and height was assessed to the nearest 0.1 cm using a stadiometer (SECA Corporation, Model 222, Germany). After anthropometric measurements were taken, participants completed a dynamic warmup that consisted of two sets of twenty meters of each of the following: high knees, butt kicks, lunges, high leg kicks, inchworms, and backwards runs. Participants then performed two sets of five repetitions in the HPC at 50% of their estimated 1RM. From this point 1RM testing continued as described by procedures from the National Strength and Conditioning Association (Haff & Tripplett, 2016). Athletes were instructed to begin the lift from the mid-thigh position and were allowed to begin with a countermovement in which the bar passed no lower than the top of the knee. For the lift to be counted, the athlete had to perform the catch with the thighs above parallel and stand up to a fully erect position. Athletes were instructed to perform the lift as rapidly as possible.

Testing sessions two and three utilized the same warm-up as testing session one, after which all athletes performed 3 consecutive repetitions of the HPC at loads of 30%, 60%, and 90% in testing session two and 40%, 50%, 70% and 80% of their 1RM in testing session three. These repetitions were performed in a consecutive fashion to mimic a typical weightlifting training session and two testing sessions were used to help mitigate any cumulative fatigue that may have occurred while performing seven sets of a HPC. Loads were tested in a random counterbalanced order and four minutes of rest was provided between each tested load.

Data Analysis

A TENDO Unit (Model V-620, Tendo Sports Machines, Slovak Republic) linear position transducer was attached at the center of the barbell to record barbell displacement data. A movement filter of 35cm was applied to the microcomputer to ensure only relevant movement data was captured, as recommended by TENDO Sport. The TENDO unit contains a microcomputer connected to a laptop which propa-

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gates the raw barbell displacement data via the TENDO unit computer software. From the recorded barbell displacement data velocity, force, and power are estimated. Peak and mean power, velocity, force, and RFD for each repetition was calculated using the mass of the barbell only (Flores et al., 2007, Hori et al., 2006). All variables were automatically calculated from barbell displacement via the TENDO unit software except for instantaneous RFD which was calculated by dividing change in force by change in time.

Statistical Analysis

For mean and peak power, velocity, force, and RFD the average of the three performed repetitions was used for statistical analysis. Eight separate one-way repeated-measures ANOVAs with relative load as the within subject factor (30%, 40%, 50%, 60%, 70%, 80%, 90% 1RM) were conducted for peak and mean power, velocity, force, and RFD. Effect sizes were calculated using partial eta squared (ηp^2) for overall ANOVAs. Post hoc comparisons were conducted using a Bonferroni correction and effect sizes were calculated between the load which optimized the variable and all other loads using Hedges' g. Greenhous-Geisser adjustment was applied when sphericity was violated and an alpha level was set at .05 for all statistical procedures.

Results

Velocity

External load has a significant main effect on both average ($F(2.92, 43.79) = 27.09$, $p < 0.001$, $\eta p^2 = 0.64$) and peak ($F(2.94, 44.09) = 29.62$, $p < 0.001$, $\eta p^2 = 0.64$) velocity. An external load of 30% 1RM produced the greatest average velocity which was significantly greater than 50%, 60%, 70%, 80% and 90% of 1RM ($p < 0.05$, g = 0.83, 1.17, 1.21, 1.65, 1.93) but was not 40% 1RM ($p > 0.05$, g = 0.47). The greatest peak velocity occurred at 30% 1RM which was greater than 50%, 60%, 70%, 80% and 90% of 1RM ($p < 0.05$, g = 0.87, 1.13, 1.30, 1.67, 2.00) but not 40% 1RM ($p > 0.05$, g = 0.47).

Force

External load had a significant effect on both average ($F(1.25, 18.79) = 307.41$, $p < 0.001$, $\eta p^2 = 0.95$) and peak ($F(2.82, 42.35) = 111.83$, $p < 0.001$, $\eta p^2 = 0.88$) force. An external load of 90% 1RM produced the greatest average force which was significantly greater than 30%, 40%, 50%, 60%, 70%, and 80% of 1RM ($p < 0.05$, g = 4.04, 3.20, 2.40, 1.76, 1.07, 0.59). The greatest peak force also occurred at 90% 1RM which was significantly greater than 30%, 40%, 50%, 60%, 70%, and 80% 1RM ($p < 0.05$, g = 2.82, 1.93, 1.41, 1.13, 0.42, 0.26).

Power

External load had a significant effect on average ($F(2.77, 41.52) = 99.51$, $p < 0.001$, $\eta p^2 = 0.87$) and peak ($F(2.32, 34.75) = 33.90$, $p < 0.001$, $\eta p^2 = 0.69$) power. Average power was maximized at an external load of 90% 1RM which was greater than 30%, 40%, 50%, 60%, and 80% of 1RM ($p < 0.05$, g = 2.20, 1.73, 1.22, 0.88, 0.27), but not 70% 1RM ($p > 0.05$, g = 0.35). Peak power was maximized at 70% 1RM which was significantly greater than 30%, 40%, and 50% 1RM ($p < 0.05$, g = 1.28, 0.91, 0.63) but not than 60%, 80%, and 90% of 1RM ($p > 0.05$, g = 0.48, 0.03, 0.01).

Rate of Force Development

Finally, external load had a significant effect on average ($F(3.10, 46.54) = 8.42$, $p < 0.001$, $\eta p^2 = 0.36$) and peak ($F(2.28, 34.19) = 3.57$, $p = 0.034$, $\eta p^2 = 0.19$) RFD. An external load of 70% 1RM produced the greatest average RFD which was significantly greater than 30% and 40% 1RM ($p < 0.05$, g = 1.05, 0.71) but not than 50%, 60%, 80%, and 90% of 1RM ($p > 0.05$, g = 0.49, 0.32, 0.17, 0.01). The greatest peak RFD occurred at 90% 1RM which was greater than 30% and 40% of 1RM ($p < 0.05$, g = 0.99, 0.93), but not than 50%, 60%, 70%, and 80% 1RM ($p > 0.05$, g = 0.66, 0.14, 0.25, 0.33). Results from pairwise comparisons can be found in Figure 1 while means and standard deviations for all external loads across all measure variables can be found in Table 1.

Table 1. Mean and Peak Barbell Velocity, Force, Power, and Rate of Force Development across Training Loads

Variables	Load						
	30% 1RM	40% 1RM	50% 1RM	60% 1RM	70% 1RM	80% 1RM	90% 1RM
Peak Velocity (m/s)	2.30 ± 0.38	2.15 ± 0.26	2.03 ± 0.21	1.93 ± 0.26	1.92 ± 0.16	1.81 ± 0.15	1.70 ± 0.18
Mean Velocity (m/s)	1.69 ± 0.31	1.56 ± 0.22	1.47 ± 0.19	1.37 ± 0.21	1.39 ± 0.14	1.29 ± 0.12	1.21 ± 0.13
Peak Force (N)	580 ± 195	729 ± 268	886 ± 253	937 ± 291	1133 ± 337	1189 ± 290	1265 ± 272
Mean Force (N)	223 ± 46	289 ± 69	371 ± 78	431 ± 95	502 ± 119	565 ± 120	643 ± 136
Peak Power (W)	909 ± 418	1074 ± 450	1230 ± 400	1282 ± 465	1526 ± 517	1514 ± 387	1520 ± 394
Mean Power (W)	387 ± 136	464 ± 153	556 ± 168	610 ± 207	721 ± 231	745 ± 205	804 ± 224
Peak RFD (N/s)	7061 ± 3644	8192 ± 4535	9756 ± 4703	12239 ± 13110	11982 ± 6805	11518 ± 5969	13698 ± 6780
Mean RFD (N/s)	2431 ± 952	2930 ± 1271	3355 ± 1200	3528 ± 2158	4233 ± 2171	3915 ± 1389	4212 ± 1376

Note. m/s = Meters per second, N = Newtons, W = Watts, RFD = Rate of Force Development; N/s = Newtons per second: 1RM = 1 Repetition Maximum

Discussion

This study examined average and peak force, barbell velocity, power, and RFD loading profiles in high school male athletes performing the HPC. The current study saw that external load had a significant effect on peak power which was greatest at 70% 1RM and significantly greater than 30-50% 1RM. Additionally, average power was maximized at an external load of 90% 1RM which was which was significantly greater than 30-60% 1RM and 80% 1RM, but not 70% 1RM. These findings indicate that when training to maximize power output in youth, male athletes, external load prescriptions between 70-90% of 1RM are optimal.

These results are comparable to the results seen in older, stronger athletes. In two separate groups of trained college males (hang clean 1RM: 104.89 ± 15.10 kg; 111.12 ± 20.40 kg), peak power was maximized at 65% and 80% 1RM, though these were not significantly different from other loads tested in the respective studies (Suchomel et al., 2014A; Suchomel et

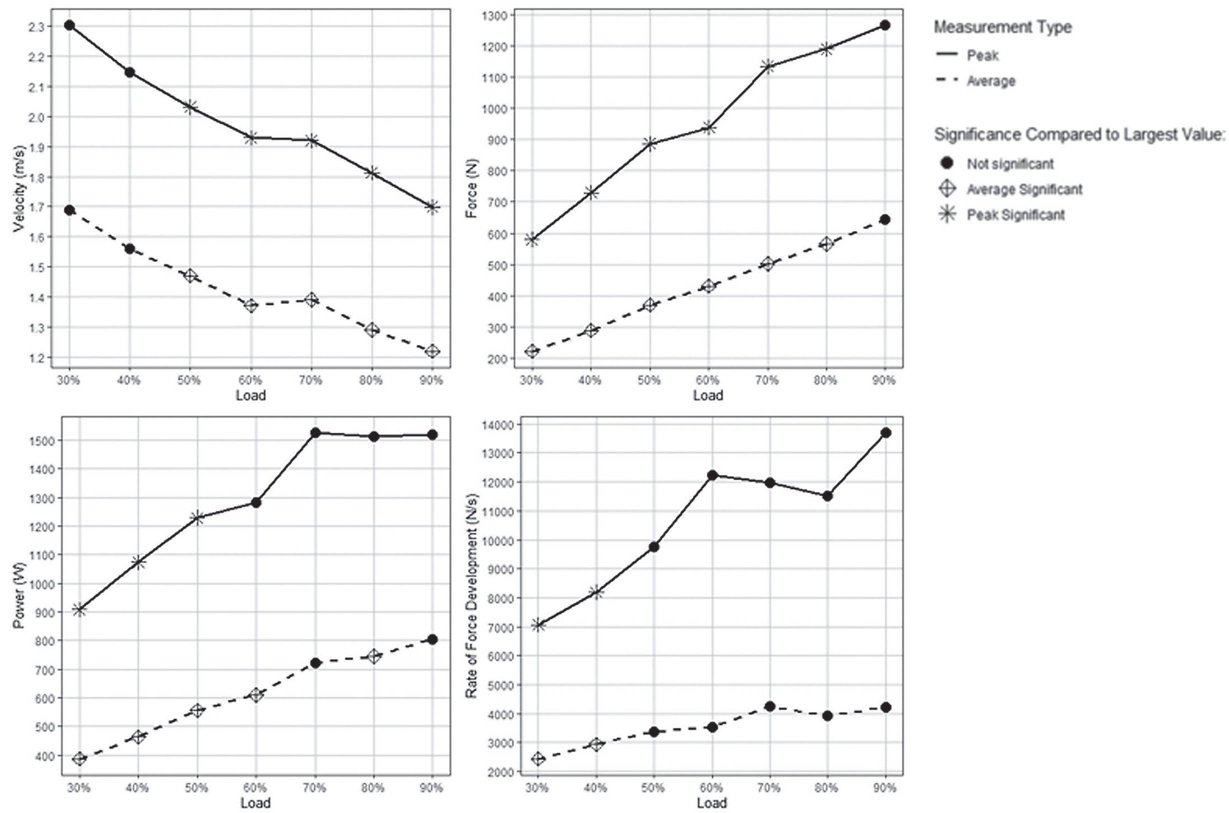

Figure 1. Changes in peak and average power, force, velocity, and rate of force development across loads.
Note. m/s = meters per second; N = Newtons; W = Watts; N/s = Newtons per second

al., 2014B). Similarly, Kilduff et al (2007) found that in professional rugby players (HPC 1RM: 107 ± 13 kg) peak power was maximized at 80% 1RM which was significantly greater than 30 and 40% 1RM. Similar results were seen in colligate weightlifters (hang clean 1RM: 107 ± 18.8kgs) who maximized both peak and average power at 70% of 1RM which was significantly greater than 30 and 40% 1RM. Combined with the present study results, it would appear that external loads between 65-80% 1RM are capable of maximizing power production in a wide variety of athletes independent of strength level.

The youth athletes tested in this study produced their greatest peak and average forces at 90% of 1RM, which is congruent with other research examining force output during the HPC in different populations (Kilduff et al., 2007; Suchomel et al., 2014A; Suchomel et al., 2014B). As 90% 1RM was the greatest external load in this study, it is logical that this load produced the greatest force. However, when examining barbell velocity, the youth athletes in this study maximized their peak and average barbell velocity at 30% 1RM which was significantly greater than 50-90% 1RM. These results are contradictory to other studies which examined barbell velocity in stronger athletes where barbell velocity was maximized between 45-60% 1RM. Only one of these studies noted a significant effect of external load on barbell velocity, and all lacked any general trend where velocity decreased as load increased (Kawamor et al., 2005; Kilduff et al., 2007; Suchomel et al., 2014A; Suchomel et al., 2014B). Examining all of these results together, it would appear that stronger athletes are more capable of maintaining higher barbell velocities at heavier loads while weaker athletes need lighter loads to produce maximal barbell velocity.

Rate of force development is a widely evaluated characteristic of explosive athletes because it indicates an athlete's ability to produce high forces at high velocities (Maffiuletti et al., 2016). Maximizing RFD requires the optimal interplay of barbell velocity and force production, despite the fact that maximal barbell velocity often occurs at low external loads while maximal force production requires high external loads. It has been suggested that to increase a person's RFD, it is necessary to train with high movement velocities (Blazevich et al., 2020). However, recent studies have indicated that stronger athletes have greater success enhancing their force-velocity profiles through weightlifting and plyometric training than their weaker counterparts (James et al., 2018; James et al., 2020). As it has been shown stronger athletes are capable of maintaining barbell velocities across a wide range of relative external loads (Kilduff et al., 2007; Suchomel et al., 2014A; Suchomel et al., 2014B), it is a logical extension that these athletes may obtain the benefits of heavy training at high velocities. Conversely, the less developed youth athletes in this study required a lighter external load to maximize barbell velocity which decreased as load increased. With the popularization of weightlifting exercises to enhance athletic performance in youth population, this makes for an interesting paradigm when examining optimal loading parameters for younger athletes.

The present study saw both peak and average RFD maximized at 90% 1RM which was significantly greater than 30 and 40% 1RM. These RFD results are similar to those seen in professional rugby players where peak RFD occurred at 90% 1RM, though this was not significantly greater than the other external loads tested (Kilduff et al., 2007). However, collegiate weightlifters have been shown to maximize peak RFD at a lower relative intensity of 60% 1RM, but again this was not significantly greater than any other loads tested (Kawamori et al., 2005). The lack of significant differences seen in both these

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studies suggests that stronger athletes may be capable of maximizing RFD across various loads in the same way they are capable of maintaining barbell velocity across loads. Conversely, the weaker athletes in the present study seem to require relatively heavy loads to maximize RFD, indicating the primary factor in developing RFD in weaker athletes is maximal force production. This implies that when developing young athletes, it may be necessary to first place emphasis on maximal force development prior to training to enhance the force-velocity profiles of youth athletes.

One potential limitation to this study was the use of a linear transducer device which is not capable of distinguishing horizontal from vertical displacement of the barbell and can in some instances overestimate power. Future studies should examine this population utilizing force plate technology combined with a linear transducer to present the most accurate force, power, RFD, and velocity data for youth athletes performing weightlifting variations.

Conclusion

The present study examined several force-velocity qualities in youth athletes who maximized peak power at 70% of 1RM, which is congruent with similar studies in different populations suggesting that loads of 65-80% 1RM are optimal for maximizing power in most athletes. The present study saw barbell velocity maximized at 30-40% 1RM while RFD was maximized at 90% of 1RM. These results differ from stronger athletes, suggesting the ability to produce maximal force heavily influences youth athletes' ability to maximize RFD. Athletes are trained under a variety of systems which seek to maximize the athletes' potential and often focuses on specific strength qualities during training blocks or training sessions. When optimizing the RFD is the primary objective of a training session, strength level and developmental phase of the athlete should be considered when prescribing external load. For coaches working with youth athletes, it may be necessary to introduce heavy strength training to increase the athletes' overall strength levels and maximize muscular strength adaptations prior to being concerned with enhancing barbell velocity. Future studies may work to establish cut points that will help coaches and practitioners know when athletes have gained enough maximal strength to make maximal velocity training a more valuable component of training.

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ORIGINAL SCIENTIFIC PAPER

Marketing Concept in Elite Team Sports Clubs in Serbia: Impact of Leadership Styles, Organizational Learning Culture, and Climate for Innovation

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Abstract

This research tested the interactions among organizational learning culture, leadership styles, climate for innovation, and marketing concept of sports clubs in team sports. The study included elite sport managers (N=118), from four team sports (football, basketball, handball, and volleyball), who participated in the highest rank of national competition in Serbia. The organizational learning culture was measured with attitudes of respondents about the organizational learning culture at individual, team or group level, and organization as dichotomous variables, while leadership styles used the MLQ self-assessment questionnaire. The climate for innovation scale was measured with scales for assessing organizational support for creativity, maladaptation, support for innovation, and resource supply. The presence/absence of components of the different marketing mix aspects was measured as a four-dimensional variable for evaluation marketing concept. The results supported the mediation and path models. Direct effect to variable marketing concept is noticed only in the organizational learning culture, while climate for innovations and leadership style did not have a direct effect on the marketing concept. Indirect effects revealed that the status of the sports branch, the market position of each club in its sport competitive results, and the education background of managers' impact marketing concept in team sports in Serbia. The theoretical and practical contributions of obtaining results are discussed.

Keywords: *organizational culture, innovation climate, sports marketing*

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Introduction

A modern approach in the management of sports organizations requires the adaptation of the sports business to the tendency to quickly abandon the traditional and conservative ways of running sports organizations. This adaptation needs consistent following „puls“ of sports market with creating proactive business strategy for leading sports organizations. However, this management process is challenging because the „sports industry has a much more unpredictable nature than most other industries“ (Popovic, 2017:37). Maksimović and

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Raič (2007) see the marketing approach in solving problems in old or European sports as an essential factor in adapting such sports in a changing environment. Such changes require accepting the marketing concept and organizational innovations imposed by successful sports clubs in more developed leagues and competitions. Successful sports organizations have previously integrated these elements as crucial factors in achieving competitive and business success.

Comparison of Serbian with today's successful international sports clubs, it is evident the differences that successful organizations achieved by accepting numerous innovations in various aspects: technological, training, financial, marketing, and organizational. All this requires sports organizations to create such an external and internal environment that will enable the creation of human resources to implement the necessary changes and introduce the necessary innovations to progress.

A deeper analysis includes an evaluation of the circumstances for applying the marketing concept and an examination of the contextual factors in which the innovative changes imposed by the modern sports business are accepted or not accepted. It can be characterized as a degree of managerial support and encouragement for employees to take the initiative in their work environment that allows the organization's current capacity of all available resources. Accordingly, it is necessary to examine how leaders in Serbian sports implement organizational innovations and how favorable the climate is for their acceptance. One of the intentions of this paper is to reveal the gap between the available organizational resources of sports organizations in Serbia and the willingness of managers to accept the necessary progressive innovations. The focus of scientific research is on team sports, which can rightly be considered national sports in Serbia, which are a reflection of national pride, interest, and overall progress.

Paper aims to test the relations of an organizational learning culture, leadership styles, and climate for organizational innovations and the marketing concept in sports clubs in team sports in Serbia.

Theoretical framework

Organizational Learning Culture, Transformational Leadership, Climate for Innovation, and Marketing Concept, and Their Interrelationships

An organization that learns continuously and transforms by expanding its capacity to create its future requires a unique environment. Creating such an environment means removing obstacles to learning and encouraging and rewarding the positive work characteristics of the members of the organization (taking risks, finding a different solution to the problem, new initiatives of employees). Aware of the possibility that the combined knowledge of individuals, teams, and ultimately the entire organization, with clearly set norms of behavior of all its members, can improve the achievement of organizational goals, managers are paying more attention to creating such a business environment. A culture of learning encourages individuals and entire organizations to increase their knowledge and expertise on an ongoing basis. Further, Pasebani, Mohammadi, Yektatyar (2012) found a positive relationship between organizational learning culture and job satisfaction with internal service quality in sports organizations. On the same line, some authors emphasized the application of performance management in an elite sport where the vision and culture of sports organizations can impact athletes' performance (Armstrong, 2019; Feddersen et al., 2020).

Contemporary leadership literature relies heavily on three typologies of leadership behavior: transformational, transactional, and non-transactional laissez-faire leadership (absence of leadership). Within the framework of transformational leadership, five factors have been singled out: (1) Idealized influence (attributed), (2) Idealized influence (behavior), (3) Inspirational motivation, (4) Intellectual stimulus, (5) Individual consideration. There are two factors within transactional leadership: 6) Exception management - active, and (7) Potential reward, and two factors within non-leadership: (8) Exception management - passive and (9) fair leadership. Consequently, a growing number of researchers in this approach recommend that sports leaders be encouraged and encouraged to “train” transformational leadership. The positive impact of transformational leadership at different levels in the organization (individual, team, whole organization) was shown by Wang (2011) in a meta-analysis that states his most substantial influence at the team level. Based on that, it is possible to more efficiently realize the set business ventures, easier acceptance of the desired innovations, and adapt to change. Therefore, outstanding results can be expected from a group of people who work together with trust and complementarity and have common goals beyond individual goals. The vision of applied leadership styles across organizational learning culture is expected to contribute to progress in for-profit and non-profit sports organizations (Megheirkouni, 2017).

From the very presence of the organizational climate, it is clear that it is a vital prerequisite to consider, analyze and accept or reject the necessary organizational innovations. Therefore, it is not surprising that a growing body of research examines how organizations foster innovation and creativity and focus on the organization's individual, group, and team levels. As the essential leadership qualities, creative environment, creativity, and innovation occupy an important place in many industries, including sports. The biggest challenge for modern sports organizations is innovation and undertaking various activities for their implementation, i.e., human resources within them must find a way to turn the planned strategy into a successful result. All this requires sports organizations to create such an external and internal environment that will enable the creation of human resources to implement the necessary changes and introduce the necessary innovations to progress. Some authors state that the history or tradition of sports organizations can influence deterrence from innovative strategies (Smith & Shilbury, 2004), and Wolfe, Wright & Smart (2006) emphasize the importance of innovation among champions (successful clubs) who have a long tradition in professional sports contexts. The vital role of dimensions of organizational climate in the prediction of innovation in sports clubs of different levels of competition is training and innovation (Escamilla-Fajardo, Núñez-Pomar, and Parra-Camacho, 2019).

The relationship of an organizational learning culture, leadership styles, and climate for innovation are of practical and theoretical value for sports marketing and management. Findings from previous research identified several dimensions essential for defining all determinants that impact sports clubs' innovations and marketing concepts. Thus, Svensson, & Mahoney (2020) emphasized the organizational culture, leadership, paid staff, infrastructure, and financial resources as the main contributors to social innovation in sport.

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Further, an essential role in mediation is supporting innovation (Bosselut, Guilbert, & Chareyre, 2020), one dimension of organizational climate, which significantly influences employees' attitudes related to their achievement (Tuna, 2014). In that atmosphere for support for innovation, organizational creativity is determined from the work environment, employee social interactions, and creativity (Smith, & Green, 2020). These authors highlighted that the sports industry could consider as unique in its approach to creativity management. Therefore, certain factors that generate a successful innovation in marketing concept, from management's point of view, can be divided into external and internal.

Proposed Hypothesized Model and Study Hypotheses

The research objectives were (1) to test if organizational learning culture, leadership styles, and climate for innovation have a direct impact on marketing concept, and (2) to examine whether relationships between characteristics of sports club and his environment and marketing concept is mediated by organizational learning culture, leadership styles and climate for innovation. As briefly discussed above, the theoretical model in Figure 1 encompasses all hypothesized dimensions (variables) and their relationships in a way that defines cause-and-effect relationships that determine the variability of the dependent variable Marketing concept.

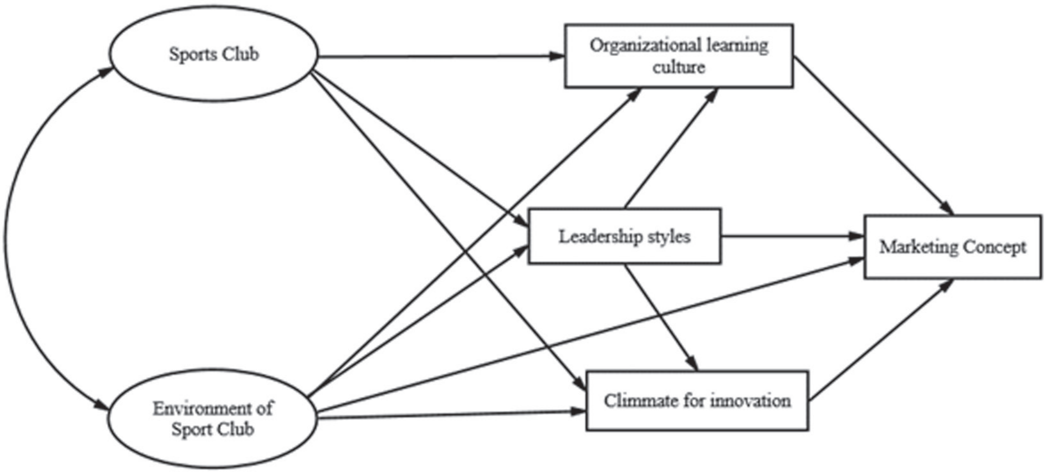

Figure 1. Proposed hypothesized model

The core of the model is the hypothesis about the conditionality of the marketing concept, the general status of marketing, and the circumstances for its application in the organization. The model is conceived on the principle of a „black box" (systems whose input and output are known, and internal connections need to be revealed - at first, they are only theoretically assumed). The entrance to the system is known, and these are the internal characteristics of the sports organization (sports branch, club type, facilities, staff, and finances) and its external environment (sponsors and the local community). The mediator dimensions in this model are organizational learning culture, leadership style, and climate for innovation. Finally, the exit from the system is known - marketing concept - as a dependent variable that measures the presence or absence of a marketing concept in a sports organization or is an indicator of sports and business success of a sports organization.

External factors for applying the marketing concept of management are sports branch, type of club, facilities, staff, finances, sponsors, local community. Inadequate resources for the application of marketing result in poor preconditions for applying its concept. From that aspect, the first and second hypothesis is related to characteristics of a sports organization and her external environment of sports organizations:

Hypothesis 1_0: The characteristics of a sports organization have no mediating effect on the marketing concept.

Hypothesis 1_a: The characteristics of a sports organization have a mediating effect on the marketing concept.

Hypothesis 2_0: The external environment of a sports organization has no mediating effect on the marketing concept.

Hypothesis 2_a: The external environment of a sports organization has no mediating effect on the marketing concept.

After external dimensions that affect the marketing concept, defined the following hypotheses from internal dimensions (mediators) were set:

Hypothesis 3_0: Organizational learning culture has no positive direct relationship with marketing concepts.

Hypothesis 3_a: Organizational learning culture has a positive direct relationship with marketing concepts.

Hypothesis 4_0: Leadership styles have no positive direct relationship with marketing concepts.

Hypothesis 4_a: Leadership styles have a positive direct relationship with marketing concepts.

Hypothesis 5_0: Climate for innovation in sport has no positive direct relationship with marketing Concept.

Hypothesis 5_a: Climate for innovation in sport has a positive direct relationship with marketing Concept.

Methods

Data Collection

The questionnaire was forwarded through national branch federations and associations to ensure the best possible research treatment in sports clubs. An additional motivation of the respondents for the most careful approach to filling in the submitted questionnaires was the opportunity to get a brief overview of the obtained results based on the research itself.

Considering that 80.5% of the respondents expressed a desire to receive feedback, i.e., a copy of the obtained results, it can be considered that there was a high motivation of the respondents to participate in the conducted research. The percentage of clubs included in the sample was 78.5% of all existing clubs in the highest rank of the competition, ie, 44 out of 56 clubs in all team sports. The number of clubs by sports that took part was as follows: football - 12, basketball - 10, handball - 10 and volleyball - 12 clubs. Managers from 12 sports clubs in the total sample of sports clubs (21.5%) were absent from the respondents because they did not fulfil their obligations on time and submitted the required information in the questionnaire.

Study Sample

The sample of respondents in this research consisted of 118 available managers of different levels in the organizational structure of sports organizations from four selected collective sports (football, basketball, handball, and volleyball), which institutionally belong to the highest rank of competition in Serbia (Table 1). The reason for selecting the team sports organizations is based on that these sports organizations in Serbia have been marked for decades as the most exciting and attractive to various stakeholders.

Within each sports organization-club, the following are included in the survey: (1) management representatives (president, secretary, etc.), (2) middle-level managers (marketing, finance sector, etc.), (3) professional staff representatives and leaders of the first competition teams. Namely, these are managers whose work depends on applying the marketing concept of management in sports clubs.

Table 1. Socio-demographic characteristics of the respondents

Variables		N	%
Sex	Male	101	(85,5%)
	Female	17	(14,5%)
Age	M=43,49 SD=10,1		
Nationality	Serbian	102	95,3
	Montenegro	2	1,9
	Bosnian	2	1,9
	The others	1	0,9
Education	Primary school	0	0
	Secondary school	23	20,0
	High School	29	25,2
	Bachelor	56	48,7
	Master	7	6,1
	PhD	0	0
Qualification	Sports and physical education	30	40,5
	Economy	18	24,3
	Business / related degree	12	16,2
	Diploma in Marketing	12	16,2
	Certificate in marketing	2	2,7
Ex-sport status	Municipal	4	4,9
	Zonal	4	4,9
	Provincial	11	13,4
	Republican	33	40,2
	International in the country	12	14,6
	International abroad	18	22,0
Role / position in management club	Youth coach	12	10,5
	First team coach	15	13,2
	Club secretary	27	23,7
	Chief Accountant	0	0
	Club director	20	17,5
	Club president	6	5,3
	Head of Marketing Department	7	6,1
	Some other function	27	23,7

The Research Instruments

Respondents, managers in sports clubs, were given the task of answering a structured questionnaire was used to measure the following variables:

Organizational learning culture was measured using 21 items with scales related to three levels of organizational learning: individual, team or group, and organization as dichotomous variables, about whether the items are appropriate/unsuitable for a sports organization. This questionnaire for researching the organizational culture of learning in sports organizations was applied by Xie (2005).

Leadership style: To collect information on respondents 'leadership styles, an MLQ self-assessment questionnaire was developed, a form developed by Avolio & Bass (2004) with 45

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items, with an inventory of respondents' leadership style characteristics (measured by the Likert scale with five degrees), and for its reproduction in this study, the necessary permission was obtained from the publisher Mind Garden, Inc., Menlo Park, CA USA. All scales of leadership style (transformational, transactional, and liberal behavior) have four items: Idealized Influence (attributed), Inspirational Motivation, Intellectual Stimulation, and Individualized Consideration. Transactional leadership contained the following factors: Management through exceptions (Active), Management through exceptions (Passive), Potential Reward, while within the liberal factor Lesse-fair leadership.

Climate for Innovation scale, was measured with 16 items with scales for assessing organizational support for creativity, maladaptation, support for innovation, and resource supply as measured by the Likert scale with 5 degrees. This inventory was proposed by Saross, Gray, Densten, Parry, Hartican, Cooper (2005) based on a survey of leadership, organizational climate, and innovation in Australian organizations.

The variable Finance has calculated the difference between total net gains and total net losses.

The marketing concept of sports organizations is a four-dimensional variable that is constituted based on the obtained results on the presence/absence of components of the marketing concept: (1) human resources, (2) financial resources, (3) content of sports offer (organizational), (4) conditions of sports facility where the club plays matches (training-technological), which were measured by the Likert scale with 5 degrees. It is understood that the relationships within the system are such relationships that affect the variation of the output variable of the Marketing concept, i.e. that its values are 0 = there is no application of the marketing concept or 1 = there is a Marketing concept - depending on the connection of dimensions (represented by extracted/sieved and composite variables). Accordingly, all sports clubs are classified in one of 16 defined categories.

Data analysis

The statistical analysis of the research included several phases:

Firstly, an α reliability test was performed for each questionnaire segment separately. After that, the calculation of basic descriptive statistics for all variables by questionnaire segments. Further, the final stage of the analysis consisted of performing: Path-analysis, where the whole procedure was performed in AMOS, version 21.0 - as its dedicated statistical and graphical solution. Full model coefficients (arrows) from a series of layered multiple regression analyses (path coefficients are beta coefficients from regression analysis) help create an empirically based picture of the factors that determine the research phenomenon or marketing concept. It can be stated that this is a saturated model whose reduction based on tests of empirical variables should establish a model that best shows the situational, real data obtained by surveys in sports clubs. The process of accepting all dimensions required implementation of the fitting model of empirical data passed through several fit indices: Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and the Non-Normed Fit Index (NNFI). Subsequently, internal fit indices with factor loadings and the inter-item reliability of the constructs above were carried out using Cronbach's alpha, Composite Reliability (CR), and Average Variance Extracted (AVE) according to Hu, & Bentler (1999).

The reduction of factors that explains the marketing concept is achieved based on the principle of parsimony (simplification). This model is a macro-model of research and based on it, using several submodels, direct, indirect, and total effects between all observed variables in the model were examined. To better understand the functioning of the mechanisms of action between the components within the starting points of the marketing concept, this research used an approach that involved the analysis of mediation. Mediation analysis (according to Judd & Kenny, 1981; Baron & Kenny, 1986) - to better understand the functioning of the mechanisms of action between components within an empirical research model.

Two models for analysis were prepared: 1) model for mediation analysis, and 2) model for path-analysis. The first model was supposed to show the details of the connection and the effects - from which all the strong, credible connections were seen. The second model - reduced based on the results of the first stage, showed how the attitude of clubs towards the acceptance of the marketing concept is formed.

Results

The obtained results of reliability test (α) by segments are as follows: Leadership Questionnaire, α = 0.84; Organizational learning culture, α = 0.87; Climate for organizational innovation, α = 0.84; Sports marketing, α = 0.97. These values are acceptable (>0.75), suggested recommendations by Nunnally and Bernstein (1994).

Variables that meet the normality requirements and the conditions necessary for performing multivariate statistical

Table 2. Descriptive variable sample statistics

	Min	Max	Mean	SD	Sk	Ku
Sports branch	1	4	2.40	1.17	0.16	-1.46
Educational background	2	5	3.42	0.87	-0.36	-0.82
Assets	1	3	2.25	0.76	-0.44	-1.14
Club type	1	9	5.43	3.17	-0.21	-1.60
Finance	0.00	13.01	6.88	3.33	-0.49	-0.37
Place	1.00	26.00	5.23	6.22	1.85	2.59
Sponsor	1	2	1.81	0.39	-1.56	0.44
Leadership style	1	5	3.71	1.28	-0.73	-0.63
Learning culture	0	1	0.76	0.26	-1.10	0.72
Innovation	2.18	4.75	3.42	0.51	0.07	-0.38
Marketing concept	1.00	2.00	1.52	0.50	-0.10	-2.02

analyses (path-analyzes) were selected. The state of coverage of the multivariate analysis model has been met (at least 10 cases/ respondents per model element - the initial theoretical model has 11 components, and the sample has 118 respondents).

Before starting the path analysis procedure, a gradual reduction of the complex initial empirical model was undertaken to obtain an optimal model appropriate to the requirement of parsimony (simplicity) that allows testing the set research hypothesis. By successive omissions from the model of tracks with a low value of beta coefficients, starting with the value less than 0.01, over the value less than 0.05 to the value less than 0.10, a total of 19 tracks were omitted.

To more fully understand the direct and indirect effects of variables entered in the saturated model, the mediation analysis of all submodels of the initial model was undertaken before concluding the correlations and effects in the reduced model. The submodels were formulated by relating two paths of direct effects - one variable from the club construct (5 variables in total) and one from the environment construct (2 variables in total) - thus obtaining ten direct effects submodels. In the end, 10 + 60 submodels were obtained, a total of 70 submodels were tested using mediation analysis (according to Kenny, for the application of Amos for mediation analysis). Using the four-step method, 12 submodels with total mediation and 18 submodels were extracted from the 60 mediation submodels shown above. In the identified submodels with partial mediation, an additional application of the Sobel test of the significance of paths with partial mediation was performed. Given the practical importance of partial mediation, the analysis focuses on the submodels of partial mediation. Applying the above mediation analysis procedure to all 18 submodels of partial mediation, the following conclusions were drawn:

- ► Medium partial mediation with a significant mediation effect (Z> 1.96) was priced on the Sponsor – Innovation - Marketing concept.
- ► Weak partial mediation with a significant mediation effect (Z> 1.96) was found on the paths: Place - Innovation - Marketing concept and Human Resources – Learning Culture - Marketing concept.
- ► Stronger partial mediation without a significant mediation effect (Z <1.96) is found only on the Sponsor - Leadership style - Marketing concept path.
- ► Other paths are characterized by weak partial mediation without significant mediation effect (Z <1.96) (two paths are weak and unreliable partial mediation).
- ► Variables - constructs of style and innovation appear as mediators on 8 tracks, while the construct of cult appears on only two paths.

This insight suggests the inclusion in further path-analysis of independent variables from the latent variable sponsor environment and location and personnel from the latent variable club. As mediators, they deserve attention primarily from innovation, then the leadership style, while the mediator variable learning culture, with its lower frequency of involvement in mediation effects, deserves attention as an additional factor. Insight into complete mediation (Table 3) points to an important characteristic of three exogenous variables: primarily the variables finance and the variables assets from the latent variable club and place from the latent variable environment, pushing the three mediator variables from the role of independent variables.

The second stage of path-analysis requires reliance on the reduced empirical model. The direct effects of the four exogenous factors that operate in the long run are primarily the status of the club, its affiliation to a particular sport, its type in terms of competitive placement, and staffing. Assets, measured by the disposition of assets and financial results, have a slight direct effect. The indirect effect of the club environment is manifested through the sponsor effect, while the wider local community environment does not have a significant effect.

The analysis of indirect effects through three mediator variables shows that the situation of clubs in specific sports and on the scale of competitive success plays a key role in the reception of the marketing concept in the observed sample of clubs. The effect of the club type on the reception of the marketing concept through the culture of learning is shown most fully thanks to the independence of this mediator concerning the management style of club management and weak susceptibility to the effect of club sponsors. The effects of both exogenous factors on learning culture, as the most influential mediator in the reception of the marketing concept, have a negative effect. With the rise of the club on the competition ladder and the acquisition of sponsors, the learning culture shows a declining trend. This result represents a certain illogicality.

The second, more complex channel of indirect effects on the acceptance and application of the marketing concept in the observed clubs is mediated by the innovative climate in club management. This climate is subject to the direct effects of the club's affiliation to a particular sport and the mediating role of the club leadership style, and the effect of the established culture of organizational learning. The effect of innovation on the reception of the marketing concept in these clubs is weak and lags behind the learning culture. Innovations are oriented towards technical, and to a lesser extent, organizational and marketing capacities of the club. Leadership style does not directly affect the adoption of the marketing concept in clubs. This mediating factor acts in isolation from most exogenous factors and is more strongly associated with the affiliation of clubs to specific sports. The leadership style of the club management is oriented towards innovations, primarily technical (training methods, equipment, etc.). This style is an essential factor in initiating an innovation climate in cooperation with changing the type of club (achieving competitive results) and the property teaming of the sports organization.

The previous statements about the strength and type of mediation were made without completely determining the significance of all paths in the reduced model. By applying the bootstrapping analysis method, a complete picture of the significance of all paths that make up the analyzed path model was obtained. Based on the results of bootstrapping analysis, it can be stated the existence of full mediation on the path of the key-> innovation (significance of the indirect effect p <0.05 and at the same time the significance of the direct effect p> 0.05).

The absence of mediation was found for all variables entered in the model, except for the paths leading from the variable button to innovation and marketing concept (except for paths for which some of the forms of mediation were previously determined). Identification of statistically significant pathways and types of mediation in a reduced model (bootstrap analysis) is shown in Tables 3, 4, and 5.

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Table 3. No mediation

	P	S	TC	SB	LS	LC	EB	A	I
Leadership styles	...	...	...	...	...	...	...	...	...
Learning culture	...	...	...	...	...	...	...	...	...
Innovation	0.11	0.11	0.00	0.09	...	...	...	...	...
Marketing concept	0.38	0.11	0.00	0.40	0.37	0.32	0.55	0.40	...

Note. P – Place, S – Sponsor, TC – Type of club, SB – Sports branch, LS – leadership styles, LC – Learning culture, EB – Educational Background, A – Assets, I – Innovation, Indirect Effects $p > 0.05$ - Two Tailed Significance.

Due to full mediation (Table 4), the role of the Type of club —> Innovation path is taken over by the Type of club — Learning culture path, whose successor is the Learning culture —> Marketing concept path, which affects the criterion variable Marketing concept. This analysis confirms the significance of the effect of partial mediation on the paths Type of club —> Learning culture, Type of club -> Innovations, Learning culture —> Innovations, as well as on the paths of direct effects with the criterion variable Sponsor—> Marketing concept, Sports branch —> Marketing concept, Learning culture —> Marketing concept and Educational background -> Marketing concept.

The previous analysis showed that the insufficient strength of connection and unsystematic mediator factors represent a limitation in the work of management in the effort to apply the marketing concept in clubs. The unconnectedness of the learning culture with the climate of innovation is a bottleneck in the marketing reconstruction of club management.

Table 4. Full mediation

	P	S	TC	SB	LS	LC	EB	A	I
Leadership styles	0.03	...	...	0.00	...	...	...	...	...
Learning culture	...	0.11	0.00	...	...	...	...	...	...
Innovation	...	...	0.05	0.04	0.09	0.00	0.40	0.09	...
Marketing concept	...	0.00	0.00	0.00	...	0.00	0.00	0.16	0.32

Note. P – Place, S – Sponsor, TC – Type of club, SB – Sports branch, LS – leadership styles, LC – Learning culture, EB – Educational Background, A – Assets, I – Innovation, Direct effects $p > 0.05$ and Indirect effects $p < 0.05$ - Direct Effects - Two Tailed Significance, $\chi2 = 864,56$, df = 214, $\chi2/df = 4.04$, CFI = 0.93, NFI= 0.92, RMSEA = 0.06..

Partial mediation (Table 5) was found on the paths: Place — Leadership style, Type of club —> Learning culture, Type of club —> Innovations, Learning culture —> Innovations, as well as on the paths of direct effects that establish variables Sponsor, Sports branch, Learning culture and Educational background with the criterion variable Marketing concept.

Table 5. Partial mediation

	P	S	TC	SB	LS	LC	EB	A	I
Leadership styles	0.03	...	...	0.00	...	...	...	...	...
Learning culture	...	0.11	0.00	...	...	...	...	...	...
Innovation	0.11	0.11	0.00	0.13	0.09	0.00	0.40	0.09	...
Marketing concept	0.38	0.00	0.15	0.00	0.37	0.00	0.00	0.20	0.32

Note. P – Place, S – Sponsor, TC – Type of club, SB – Sports branch, LS – leadership styles, LC – Learning culture, EB – Educational Background, A – Assets, I – Innovation., Total Effects – $p < 0.05$ – Two - Tailed Significance.

Discussion

Based on the applied statistical procedures, the null hypothesis H0 was tested, followed by the alternative hypotheses Ha (direct connections and indirect connections). The obtained results confirmed that: There are statistically significant correlations between the dependent variable and certain defined factors in the empirical research model, thus rejecting the basic null hypothesis. About alternative hypotheses, it has been shown that there are direct and indirect connections.

Effects on the dependent variable marketing concept were determined in 4 exogenous and 1 mediator variables. Of the indirect effects of the exogenous factor characteristics of the sports club, the following existed: club status, sports branch, type of club, and educational background (which supports H1a). Assets and financial results (balance) have a slightly indirect effect. It is noticeable that the weak financial status of sports organizations excludes its effect on the marketing concept. Such results according to the parameters for assessing the financial sustainability of sports organizations proposed by Foster, Greyser & Walsh (2006) indicate the weaknesses of domestic sports organizations in the following 6 factors: 1) Strength of the league to which clubs belong, 2) Club brand and its history and tradition, 4) Stadium where the club hosts matches, 5) City or area where the club is located and 6) Owner characteristics and club culture. Observing the following parameters, it can be concluded that the clubs rely heavily on the history and tradition of the club but that the implementation of their branding is lacking.

Numerous researches have confirmed the connection between the sports competition result with motivation and spectators' identification with the team. Various studies have as their starting point to investigate the motivational factors of individuals who are willing to invest financial, emotional, and time resources in watching and watching sporting events

(James & Ridinger, 2002; Milne & McDonald, 1999; Wann, 1995). The necessity of identification with successful teams imposes the achievement of consistently good sports results. Namely, the audience is looking for confirmation of good competitiveness in the international competition with clubs, and accordingly, during the season, there is the most significant interest in international matches. Knowing this causal connection, the clubs try to achieve notable results in the domestic competition at any cost to be placed in the international rankings of the competition, which has a stimulating effect on the entire organization. Sports organizations in Serbia must "shape" the sports offer on the market as soon as possible, which will be as competitive as possible at the regional and international level, and accordingly attract the attention of the domestic audience.

In terms of manager education, it is certain that educated managers better understand the needs of innovation and are ready for a higher degree of necessary adjustments. Mumford (2000) and Kearney, Feldman, & Scavo (2000) emphasize the need for education in the process of diffusion of innovation because new ideas and solutions require the knowledge and expertise of employees. Also, Maksimović and Raič (2012) emphasize the high share of staff in the development of services in sports, which makes staff education an important factor in marketing strategy (mix).

In addition to education, Damanpour & Schneider (2008) show that managerial and personal characteristics influence adaptation to innovation rather than demographic characteristics, while (Borins, 2000) shows that entrepreneurs with an entrepreneurial orientation see innovation as a need for change.

As for the Environment, as another exogenous factor, the indirect effect is manifested through the sponsor effect, while the wider environment (local community) has no significant impact. Therefore, H2a is partially supported).

Of the mediator variables, the only direct effect is present in the learning culture (which supports H3a). These relationships are consistent with research conducted by Williams (2010), which showed that organizational culture is associated with business success. The author cites adaptability, strong culture, vision, and employee participation as key aspects of a successful organizational culture. In general, based on the overall results of all respondents' individual, group, and organizational learning culture, it can be considered that a good organizational culture is "nurtured" in domestic clubs. However, if we look at the climate for organizational innovation, which relies heavily on organizational culture, it is noticeable that there are bigger problems with it. The weakest results concern the maladaptation factor, where over 40% of respondents point to a low level in this climate factor for organizational innovation.

This factor in the sports organization implies a climate where employees have many problems if they think and work differently and do not respect the orders received. Also, the significant problem is that many respondents see the highest degree of agreement with others as a very influential way to progress in their work environment, which indicates problems in expressing differences concerning the ruling attitudes. Certainly, a climate with as many like-minded people as possible is not desirable for implementing various innovations and creative ideas. The next problem in this segment is the unsatisfactory level of resources available to sports organizations.

Regarding other mediator variables, the following was determined: (1) Leadership style did not have a direct impact on the adoption of the marketing concept in clubs, and (2), Innovations did not have a direct effect on the Marketing concept which means that H4a and H5a are rejected. These results agree with the results of research conducted using a questionnaire based on the Hersey-Blanchard situational approach to leadership Jurak and Bednarik (2010). The obtained results led the authors to conclude that the leadership of Slovenian sports organizations is generally "blind" in terms of the importance of leadership in this context.

As budgets and human resources are often reduced in sports organizations and where leaders often need to do more with fewer resources, the ability of management to transform or inspire individuals to act in the best interests of the organization is vital. Herrera and Lim (2003) emphasize the essential importance of transformational leadership for success in sports clubs. The key factors of the "right" style of leadership in sports organizations, according to the results obtained by Maksimovic, Milosevic, Matic, and Obradovic (2011), are: (1) Specific factors that are specific to the sports organization, (2) Factors that are specific to leaders in the goal encouraging motivational needs and work expectations of employees, (3) Personal and reference factors typical of different leadership styles include the key skills, sensitivity, reasonableness, and flexibility in working with people.

With the change of innovation in the club, a mediation path is being established for clubs in sports already open to marketing influences. The mentioned intervention in the orientation of the innovation climate in the club is also contributed by the type of club in terms of its competitive orientation (Type of club) and the use of property potential that can be put in the function of marketing business performance of the club (Assets). However, it should be taken into account that the price of innovation negatively affects the adjustment by employees, so that less expensive innovations are more accepted by organizations (Rogers, 2003; Damanpour, & Schneider, 2008).

A potential limitation of the work is the application of an abbreviated form of the MLQ 5X questionnaire for self-assessment of leadership behavior by managers. More comprehensive information would be obtained by applying the second part, which refers to the form of evaluation of leaders by others. Nevertheless, the information obtained in this form of the questionnaire represents the personal perception of leadership behavior, based on which the idea of leaders' beliefs about their leadership is gained. The absence of a form of evaluation of leaders by followers in the organization was considered a practical approach, since the problem of this paper is not to examine the differences between leadership vision, on the one hand, and evaluation of their leadership by subordinates, but the perception of managers in sports organizations concerning organizational culture and marketing concept. The obtained results represent the "picture" of the leadership of current managers in our sports clubs from the group of team sports.

Considering that the obtained results represent the evaluation of the management of sports organizations concerning the current sports offer provided by our sports clubs in collective sports, it should be borne in mind that on this occasion the opinions of consumers and spectators of sports events of these clubs were missing. Additionally, each of the segments in future research (especially the sponsor's factor, the local en-

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vironment) may be covered by additional information about these phenomena. In this way, in addition to the anticipated elements of the theoretical model, it should be monitored whether there are certain modifications in the results obtained with additional effects on the sports organization of the media, clients/consumers, and other stakeholders. The space for future research is opened by the application of the experimental approach, which is almost absent in domestic research.

In general, it can be stated that the analysis of indirect effects shows that the interpretation of the Marketing concept should take into account the importance of indirect effects of the competitive type of club on innovation and learning culture, innovation, and learning culture, and places Leadership style. The results of the analysis of the partial mediation submodels show that they existed with different strengths on these paths: Weak – (1) Place → Innovation → Marketing concept. Such connections indicate that innovations are very much determined by the location where the clubs are located, which, as expected, indicates an indirect effect on the marketing concept. This shows in sports practice that innovations are not equally widespread in all clubs and that the marketing concept depends on the local environment in which it is implemented; (2) Human resources → Learning culture → Marketing concept. The connection of organizational culture with the educational capacity of the sports organization shows that the acquired education to some extent determines the "creation" of organizational culture through which its connection with the application of the marketing concept is further established. (3) Medium - Sponsor → Innovation → Marketing concept.

The expected connection that indicates that the implementation of innovations depends on the presence of sponsors, which allow improving the resources necessary for the functioning of the marketing concept. Accordingly, it can be stated that in addition to the direct effect on the marketing concept, sponsorship also acts indirectly through the creation of a more favorable climate that is more willing to accept the necessary progressive innovations.

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Number (Arabic numerals) the pages consecutively (centering at the bottom of each page), beginning with the title page as page 1 and ending with the Figure legend page.

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Original Scientific Paper

Transfer of learning on a spatial memory task

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Word count: 2,980

Abstract word count: 236

Number of Tables: 3

Number of Figures: 3

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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.

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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 7th Edition reference style. Check the Publication Manual of the American Psychological Association (2019), Seventh Edition that is the official source for APA Style, 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 or more authors: cite only the name of the first author followed by et al. and the year

- ✓ Bangsbo et al. (2008) stated that…
- ✓ In one study (Bangsbo et al., 2008), soccer players…

Works by organization as an author: cite the source, just as you would an individual person

- ✓ According to the American Psychological Association (2000)…
- ✓ In the APA Manual (American Psychological Association, 2003), it is explained…

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); separated by a semi-colon

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

2.4.3. Examples for Reference list

Works by one author
Borg, G. (1998). *Borg's perceived exertion and pain scales*: Human Kinetics.

Works by two authors
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. https://doi.org/10.1007/s00421-007-0468-x

Works by three to twenty authors
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. https://doi.org/10.26773/mjssm.2017.09.008

Works by more than twenty authors
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 & Science in Sports & Exercise, 35*(4), 697–705. https://doi.org/10.1249/01.mss.0000058441.94520.32

Works by group of authors
NCD-RisC. (2017). Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: a pooled analysis of 2416 population-based measurement studies in 128.9 million children, adolescents, and adults. *Lancet*, 390(10113), 2627-2642. https://doi.org/10.1016/s0140-6736(17)32129-3

Works by unknown authors
Merriam-Webster's collegiate dictionary (11th ed.). (2003). Merriam-Webster.

Journal article (print)
Scruton, R. (1996). The eclipse of listening. *The New Criterion, 15*(3), 5–13.

Journal article (electronic)
Aarnivala, H., Pokka, T., Soininen, R., Mottonen, M., Harila-Saari, A., & Niinimaki, R. (2020). Trends in age- and sex-adjusted body mass index and the prevalence of malnutrition in children with cancer over 42 months after diagnosis: a single-center cohort study. *European Journal of Pediatrics,* 179(1), 91-98. https://doi.org/10.1007/s00431-019-03482-w

Thesis and dissertation
Pyun, D. Y. (2006). *The proposed model of attitude toward advertising through sport*. [Unpublished Doctoral Dissertation]. The Florida State University.

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

Chapter of a book
Armstrong, D. (2019). Malory and character. In M. G. Leitch & C. J. Rushton (Eds.), *A new companion to Malory* (pp. 144-163). D. S. Brewer.

Reference to a Facebook profile
Little River Canyon National Preserve (n.d.). *Home* [Facebook page]. Facebook. Retrieved January 12, 2020 from https://www.facebook.com/lirinps/

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.

If a figure has been published previously, acknowledge the original source and submit a written permission from the copyright holder to reproduce the material. Permission is required irrespective of authorship or publisher except for documents in the public domain. If photographs of people are used, either the subjects must not be identifiable or their pictures must be accompanied by written permission to use the photograph whenever possible permission for publication should be obtained.
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.

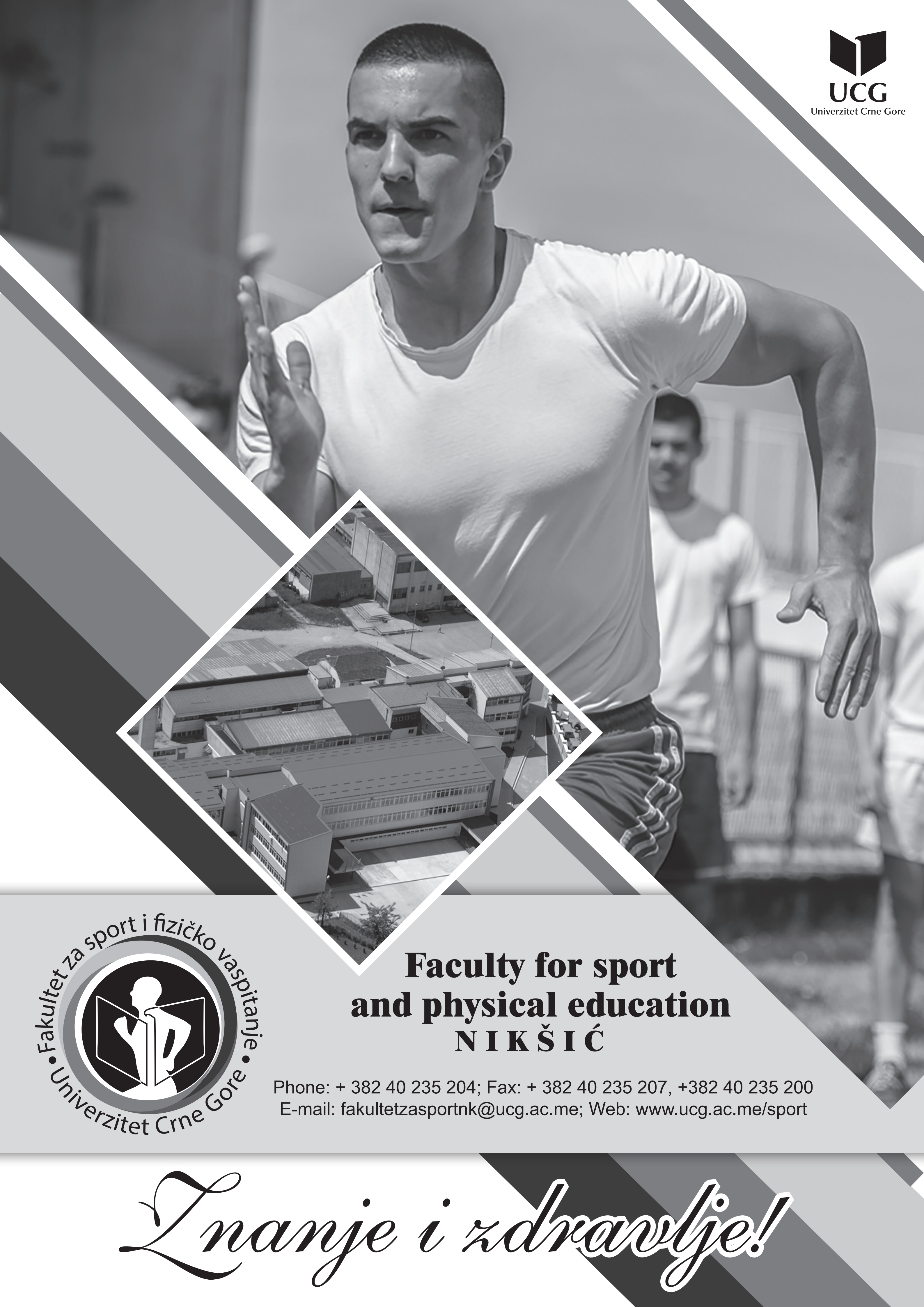
Percentage	Degrees	All other units of measure	Ratios	Decimal numbers
✓ 10%	✓ 10º	✓ 10 kg	✓ 12:2	✓ 0.056
× 10 %	× 10 º	× 10kg	× 12 : 2	× .056

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

2.8. Latin Names

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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