Genetic Variants that Influence Performance on the Wingate Anaerobic Test: A Systematic Review

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Abstract

Anaerobic performance is decisive in many sports. The Wingate Anaerobic Test (WAnT) is the most widely used test for the assessment of anaerobic performance to date. Performance in this test is influenced by many variables, including genetics. The aim of this review is to analyze the genes related to WAnT performance. A detailed search of four databases (Pubmed, Scopus, Web of Science and Cochrane Library) was conducted until February 2022. This literature search was implemented according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement. Nine eligible studies were selected from the 153 records identified. 3 articles for the ACTN3 gene, 2 for AMPD, one combined ACTN3 and AMPD, 1 article each for PPARA, UCP2 and MCT1. The genes ACTN3 and AMPD seem to report contradictory literature regarding its influence on WAnT peak power (PP), mean power and fatigue index. The MCT1 gene seems to have no influence, and the PPARA and UCP2 genes seem to have a positive relationship with PP.

Keywords: polymorphism, gene, performance, power, supramaximal

Introduction

The vast majority of sports require high intensity stimuli such as jumps or sprints (Baker & Davies, 2002), which are often decisive in the final performance. For this reason, it is very important to be able to measure anaerobic power. Different tests have been designed for this purpose, such as cycling with the Wingate Anaerobic Test (WAnT) (Capostagno et al., 2016), 20-45 seconds linear sprints in running (Krops et al., 2017) or Counter Movement Jump or Squat Jump in jumping (Wen et al., 2018). However, the most commonly used protocol for assessing anaerobic metabolism is the WAnT, which is considered the gold-standard of anaerobic testing (Bertuzzi et al., 2015; Driss & Vandewalle, 2013; Madrid et al., 2013; Minahan et al., 2007). The WAnT requires pedalling with the lower or upper limbs for 30 seconds, at maximum speed and against a constant resistance (7.5% of the participant's body mass). The most important information we can obtain from the test is (Hopkins et al. 2001): peak power (PP): The highest level of power reached during the test is usually within the first 10 seconds if the test is performed correctly; mean power (MP): The average power reached during 30 seconds; and fatigue index (FI): it represents the loss of power experienced from the moment in which the maximum power is reached and the end of the test or, in other words, FI is the rate of decrease in power during the test, expressed as a percentage of the maximum power (Castañeda-Babarro, 2021).

Conflict of interest: None declared.

There are many variables that can affect performance in WAnT. On the one hand, certain external variables may affect outcomes, such as listening to music during the test (Castañeda-Babarro et al., 2020), the resistance used in the cycle-ergometer (Hermina, 1999; Richmond et al., 2011), the warm-up carried out (Burnley & Doust, 2005; Ramierz et al., 2007) or carrying out the test with or without cleats (LaVoie et al., 1984).

On the other hand, internal variables can also influence the results achieved. It has been reported that in anaerobic tests such as the vertical jump genetic variables can play an important role in the final performance (Ostojić & Stojanović, 2010). Muniesa et al. (2016) observed how the ACE gene showed significant improvements with respect to the DD genotype in the Sargent test and the sprint speed test, while in the ACTN3 gene, the RR variable obtained improvement results with respect to the RX and XX variables in jumping and the Sargent test. Similarly, the ACTN3 and ACE genes have been related to sprint and power performance in elite athletes (Eynon et al., 2016).

In this sense, internal variables such as genetics also condition the final result of WAnT (Bondareva et al., 2017). Hanson et al. (2010) concluded that the ACTN3 genotype did not affect power output recorded in active but untrained men and young boys in the United States, whereas Atanasov et al. (2015) observed a predominance of the ACTN3 and AMPD1 genotypes in elite and sub-elite athletes compared to subjects with low levels of physical activity. In addition, Petr et al. (2014) saw how PPARA polymorphism was linked to greater power values among elite hockey players. In this sense, there are several studies related to the ACTN3 R577X polymorphism with conflicting findings. Whereas Norman et al. (2009) did not find any difference among the general population with regard to the performance of subjects with different genotypes, Kikuchi et al. (2014) reported differences in the performance of subjects (athletes) with different genotypes. Finally, Kikuchi et al. (2017) studied the influence of different genotypes of MCT1 T1470A polymorphism on WAnT performance, comparing national and international wrestlers with other less trained subjects, and found differences related to different genetic options.

Therefore, the main purpose of this systematic review was to analyze the association between genetic variants and different performance indicators in WAnT, such as. PP, MP and FI.

Methods
Literature searching strategies
The current publication is a systematic review of the genetic variants that influence performance on the WAnT. The research was conducted according to Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009; Stewart et al., 2015). A systematic search was conducted on PubMed/MEDLINE, Web of Science (WOS), Cochrane library and Scopus database. Appropriate bibliographic support was ensured with these databases, and the search was completed without being limited to any specific years, results being included until 7 February 2022. Combinations of the following keywords were used as search terms: ("Wingate MeSH" OR "Supramaximal anaerobic test MeSH") AND (Polimorphism OR Gen OR Genetic OR SNP). After conducting the initial search, the reference lists of the retrieved articles were then screened for other articles that were relevant to the topic as described by Greenhalgh and Peacock (2005). Articles were first screened by title and abstract, followed by a full-text review of all articles considered relevant.

Inclusion and exclusion criteria
To define the inclusion criteria, the PICOS model was used (O'Connor et al., 2008): P (Population): "female athletes or physically active women", I (Intervention): "wingate, C (Comparison): "same experimental condition with and placebo", O (Outcome): "physical and/or athletic performance measures" and S (study design): "random or double-blind and random design".

No filters were applied to level, gender, race or age (with participants over the age of 18 years). Inclusion criteria were: (I) There is a comparison between the WAnT results made in an identical way by the subjects; (II) Studied the effect of a genetic variable on the outcome obtained in WAnT; (III) Studies on a variety of genetic variables were accepted; (IV) studies with variations of the original WAnT protocol, assuming that it was applied to all participants in the same way; (V) only studies in which WAnT was applied to the lower body; cycling (VI) even if no PP, MP or FI data was provided.

The exclusion criteria listed below were also applied to the experimental protocols attached to the research: (I) studies that tested anaerobic metabolism but not with WAnT; (II) studies which used different outcomes other than PP, MP and FI obtained by the WAnT; (III) articles that do not relate WAnT with genetic variables; (IV) studies conducted on injured participants or on those suffering from medical conditions, injuries or drugs and (V) unpublished studies in PubMed/MEDLINE, WOS, Cochrane library or Scopus.

Study selection and data extraction
Once the inclusion/exclusion criteria were applied to each article, the following data were extracted: source of the study (author/s and year of publication); sample population (number of participants, sex and age), sample size, indicating the level of physical activity and sport discipline; intervention (test); parameters analyzed as a measure of physical/sport performance; and conclusion, the results of the effect of the gene/polymorphism on the parameters analyzed in the population. Finally, the final results of the interventions using a spreadsheet (Microsoft Inc, Seattle, WA, U.S.A) were extracted.

In addition, the snowball strategy was applied to review the reference sections of all the highlighted studies which returned relevant articles in the field of snowball strategy implementation (Palinkas et al., 2015). According to the information included in the full texts, the inclusion and exclusion criteria were applied in order to select the articles that could be included in this systematic review.

Outcome variables
The literature was examined for the effects of genetic variables on WAnT performance using the following outcome variables: PP, MP, and FI.

Quality assessment and risk of bias
To determine the quality of the evidence, the authors reviewed the considered articles and provided PEDro (Physiotherapy Evidence Database) scores for each article. Only studies with PEDro scores of 4 or higher were included in the systematic review. According to Maher et al. (2003), the PEDro scale is an 11-item scale designed for rating methodological quality of randomized control trials. Each satisfied item (except for item 1) contributes one point to the total PEDro
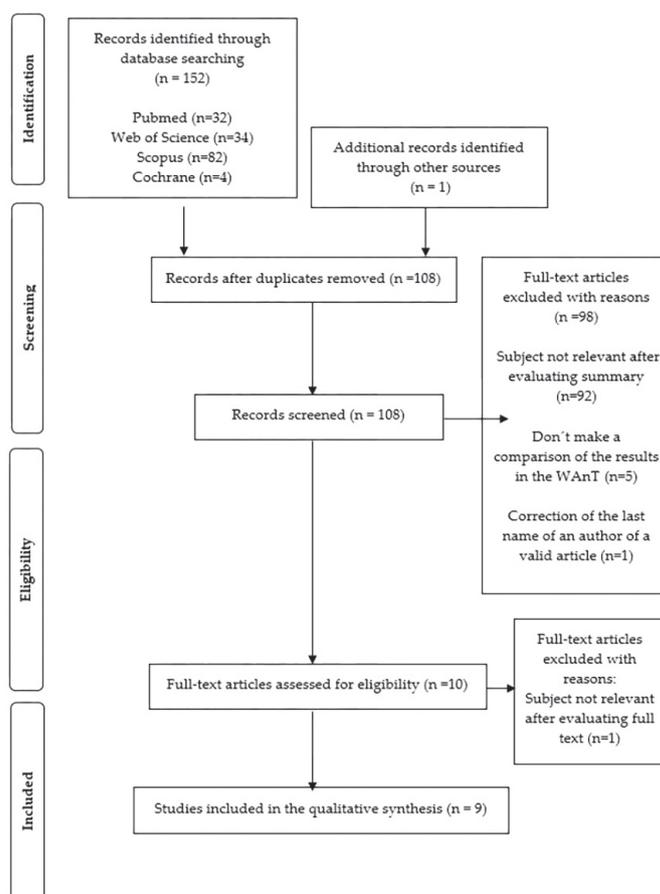
score (0–10 points). The PEDro scores were extracted from the PEDro database. If a study had not been entered into the database and scored, it was reviewed and scored by an experienced PEDro rater.

Results

Main search

Of the 153 articles that were identified through the literature search, only nine studies fulfilled all the inclusion criteria for this systematic review (Figure 1). Firstly, 45 studies were removed because they were duplicates. Of the remaining 108 articles, a total of 98 studies were removed because their abstracts were not related to the objective of the review (92), did not make a comparison of the results in the WAnT (5) and because one article was only a correction of the last name of an author of a valid article. Of the 10 full-text articles assessed for eligibility, 1 further paper was disregarded because after reading the whole article, it was concluded that it was unrelated to the genes that influence performance on the Wingate Test. Thus, the current systematic review included

Figure 1. Flow chart of study selection

Table 1. Quality Assessment with the PEDro Scale

Article	Items by number on the PEDro Scale											Total score
	1	2	3	4	5	6	7	8	9	10	11	
Hanson et al. (2010)	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y	7
Atanasov et al. (2015)	Y	N	N	Y	Y	Y	Y	Y	N	Y	Y	7
Fischer et al. (2007)	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	8
Petr et al. (2015)	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	8
Norman et al. (2001)	Y	N	Y	N	Y	N	N	Y	Y	Y	Y	6
Norman et al. (2009)	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	7
Kikuchi et al. (2014)	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	8
Bondareva et al. (2018)	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	6
Kikuchi et al. (2017)	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	8

Note. N: criterion not fulfilled; Y: criterion fulfilled; 1: eligibility criteria were specified; 2: subjects were randomly allocated to groups or to a treatment order; 3: allocation was concealed; 4: the groups were similar at baseline; 5: all subjects were blinded; 6: all therapists were blinded; 7: all assessors were blinded; 8: measures of at least one key outcome were obtained from over 85% of the subjects who were initially allocated to groups; 9: intention-to-treat analysis was performed on all subjects who received the treatment or control condition as allocated; 10: the results of between-group statistical comparisons are reported for at least one key outcome; 11: the study provides both point measures and measures of variability for at least one key outcome; total score: each satisfied item (except the first) contributes 1 point to the total score, yielding a PEDro scale score that can range from 0 to 10.

nine studies (Atanasov et al., 2015; Bondareva et al., 2018; Fischer et al., 2007; Hanson et al., 2010; Kikuchi et al., 2017; Kikuchi et al., 2014; Norman et al., 2009; Norman et al., 2001; Petr et al., 2014).

Quality assessment of the experiments
The nine studies obtained a high-quality methodology score (PEDro score ≥5/10), with a mean score of 7.2, accord-

ing to the PEDro scale (Table 1).

Genetic variables related to performance in WAnT
The characteristics of the participants and the characteristics of the protocols used in the different studies are shown in Tables 2 and 3. There were a total of 1791 participants included in the selected studies, of which at least 264 were women (the gender of some of the groups, such as the control, is not specified).

Table 2. Studies Included in the Systematic Review: Features of those Taking Part and of the Relevant Interventions

Variables	Classification	Articles
Level of participants	Not physically active	1 study (Bondareva et al., 2018)
	Physically active	3 studies (Fischer et al., 2007; Hanson et al., 2010; Norman et al., 2001)
	Athletes	4 studies (Bondareva et al., 2018; Kikuchi et al., 2017; Kikuchi et al., 2014; Norman et al., 2009)
	Elite or Sub Elite	2 studies (Atanasov et al., 2015; Petr et al., 2014)
Age of participants	18-25	2 studies (Atanasov et al., 2015; Kikuchi et al., 2014)
	18-35	4 studies (Hanson et al., 2010; Norman et al., 2009; Norman et al., 2001; Petr et al., 2014)
	18-45	1 study (Fischer et al., 2007)
	Not specified	2 studies (Bondareva et al., 2018; Kikuchi et al., 2017)
Resistance applied during the WAnT	7,5% of body weight	7 studies (Atanasov et al., 2015; Fischer et al., 2007; Hanson et al., 2010; Kikuchi et al., 2014; Kikuchi et al., 2017; Norman et al., 2001; Norman et al., 2009)
	0.091kg·kg^{-1} body mass	1 study (Petr et al., 2014)
	100 g/kg^{-1} (for men)	1 study (Bondareva et al., 2018)
Analized parameters during the WAnT	PP	8 studies (Atanasov et al., 2015; Bondareva et al., 2018; Fischer et al., 2007; Hanson et al., 2010; Kikuchi et al., 2014; Kikuchi et al., 2017; Norman et al., 2001; Norman et al., 2009; Petr et al., 2014)
	Mean power	6 studies (Atanasov et al., 2015; Fischer et al., 2007; Hanson et al., 2010; Kikuchi et al., 2017; Kikuchi et al., 2014; Norman et al., 2009; Norman et al., 2001)
	FI	1 study (Fischer et al., 2007; Hanson et al., 2010; Norman et al., 2009)
Way to obtain genetic material	Buccal cells	1 study (Bondareva et al., 2018; Hanson et al., 2010; Kikuchi et al., 2014)
	Blood	1 study (Atanasov et al., 2015; Fischer et al., 2007; Norman et al., 2009)
	Saliva	1 study (Kikuchi et al., 2017; Petr et al., 2014)
	Muscle biopsy and blood extraction	1 study (Norman et al., 2001)
Genes analyzed	ACTN3 R577X	3 studies (Atanasov et al., 2015; Hanson et al., 2010; Kikuchi et al., 2014; Norman et al., 2009)
	AMPD	2 studies (Atanasov et al., 2015; Fischer et al., 2007; Norman et al., 2001)
	PPARA	1 study (Petr et al., 2014)
	UCP2	1 study (Bondareva et al., 2018)
	MCT1	1 study (Kikuchi et al., 2017)

Note. WAnT: Wingate Anaerobic Test; PP: Peak power, FI: Fatigue index.

Discussion

A summary of the effects of different genes on WAnT performance constituted the chief aim of this systematic review. The main results indicate that while ACTN3 and AMPA have a contradictory influence (except PP in the ACTN3 gene), the MCT1 gene seems to have no influence, and the PPARA and UCP2 genes may have a positive relationship with PP. Regarding the number of articles found, it seems that the most studied polymorphisms have been ACTN3 and AMPD (ACTN3 n=3, AMPD n=2 and the two polymorphisms at the same time n=1).

According to the results, it can be observed that ACTN3 has been related to sports activities that require polymorphism, power and strength (Atanasov et al., 2015; Kikuchi et al., 2014), especially the R alleles (Atanasov et al., 2015), since

ACTN3 is a protein that serves to stabilize the contraction of fast fibres. However, in explosive and anaerobic activities like jumping there is a contradictory literature. There are some studies that found a positive relationship between the R allele of this gene and performance (Massidda et al., 2014; Pimenta et al., 2013). However, the study by Ginevičienė et al. (2011) concluded that the X allele has a positive relationship with performance, whereas others do not find any relationship (Garatachea et al., 2014; Massidda et al., 2012). It has also been observed that this gene does not influence the muscle power obtained in a WAnT after an intense session (Hanson et al., 2010) and that the gene does not condition muscle strength or sprint performance of trained women and men again obtained by a WAnT (Norman et al., 2009). Regarding WAnT, the influence of the ACTN3 gene is contradictory for both PP and MP,

whereas for FI there do not seem to be any studies to support its influence on WAnT performance. Until now it seemed that the gene was related to muscle power, but some research calls into question the positive influence of this gene (Hanson et al., 2010; Norman et al., 2009). However, some studies such as those by Atanasov et al. (2015) or Kikuchi et al. (2014) observed positive relationships. The differences in performance obtained in the anaerobic test may depend on the composition of the muscle fibres in the samples analysed, the type of training performed and the intensity and frequency (Norman et al., 2009) ultimately, to a large extent, depending on the subject. Furthermore, it should be noted that the experiments conducted focus exclusively on one test.

The AMPD1 gene regulates the cellular energy metabolism in high intensity sport activities (Atanasov et al., 2015). The AMPD1 deficiency of skeletal muscle leads to poor sport performance, a feeling of premature fatigue and a slowing of muscle contraction speed. Nevertheless, it can be argued that AMPD1 gene does not have a solid literature on its effect on the WAnT. Some sources of information also about this gene indicate that between genotypes of the AMPD1 gene, in terms of performance, there are no significant differences (Fischer et al., 2007; Norman et al., 2001), even if others say otherwise (Atanasov et al., 2015). Those contradictions may be due to the number and type of samples collected. It is not easy to gather large numbers of people who lack the gene when analysing AMPD1 deficiency, as only 2 percent of the Caucasian population develops it (Fischer et al., 2007). It should be noted that although in some cases no significant influence has been obtained in the WAnT between the ACTN3 and AMPD1 genotypes, it has been observed that the combination of both specific genes influences performance (PP) (Atanasov et al., 2015). Although there is only one research that studied the influence of this gene in WAnT on the IF variable, it appears that DMPA may have an influence on the ability to maintain "anaerobic fatigue" or anaerobic capacity (Fischer et al., 2007).

There is only one study included in this review that studied the relationship between the PPARA gene and WAnT performance, so the conclusions that can be drawn in this regard are limited. However, this gene is responsible for: fatty acid assimilation and oxidation, glucose and lipid metabolism, left ventricular growth and the regulation of the expression of genes involved in body weight control (Ahmetov & Fedotovskaya, 2015). Considering that this gene has previously been linked to performance in other anaerobic tests such as jumping (Ahmetov et al., 2013), and that the only article included in this review is along the same lines (Petr et al., 2014), it can be suggested that it may indeed have an influence on PP in this type of tests.

Regarding the UCP2 gene, it has been linked to weight acquisition and performance in sports requiring aerobic competition (Bondareva et al., 2018). In addition, it appears in most of the organs and tissues of the body, as well as in skeletal muscle. The Val/ala 55 allele of the UCP2 gene has been observed to be related to aerobic capacities and Val/ala 55 times with sports that require explosiveness (Bondareva et al., 2018). As with the previous gene, although we must be aware of the limitations of the small number of studies conducted on this gene and with this test, in view of what has been analyzed, it can be stated that the Val/ala55 polymorphism of this gene has a positive influence on the PP of the WAnT.

As for the MCT1 gene T170A, the expression of this gene increases with high intensity interval training, thus achieving lactate clearance and better regulation of muscle pH (Kikuchi et al., 2017). It can be said that the MCT1 gene T1704 appears to have no influence on the WAnT (PP and MP) and is not genotype dependent. Given its relation to lactate metabolism, it would have made sense to assess FI in the tests performed, as this value is more related to glycolytic metabolism than PP (Serresse et al., 1988).

Finally, it is necessary to take into account some limitations that condition the work. On the one hand, it is important to consider the limitations that the low number of articles found with some genes entails when drawing conclusions. On the other hand, of the three data that WAnT can report, such as PP, MP and FI, they were not measured in all the articles, limiting the study or the corresponding relationship with the gene investigated. In the case of FI, which is not found in all the included studies, it can provide valuable information on the subject's ability to withstand fatigue and relating it to genetics could also be of great interest. It is important to underline that we should not only take into account studies that use WAnT for the evaluation of anaerobic metabolism and its relationship with some genes, as there are many other tests. However, we must give the importance it deserves to a test considered as the gold standard and probably the most widely used in the scientific literature.

Conclusions

Based on the results obtained from this systematic review, the ACTN3 and AMPD1 genes seem to report contradictory literature regarding their influence on PP, MP and FI values of WAnT. The MCT1 gene appears to have no influence, and the PPARA and UCP2 genes appear to have a positive relationship with PP. Thus, this review shows the importance of genetics in one of the most important anaerobic tests. This is of great interest, as it could facilitate talent detection or even predict a subject's future anaerobic performance. However, few articles were found, so more research is needed in order to obtain more conclusive results. Furthermore, the importance of environmental and behavioral factors, as well as epigenetic variables, cannot be rejected, so the results should be interpreted with caution.

Ethical Approval Information

No Ethical Approval was necessary to present this review.

Funding

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