Understanding running performance through a holistic approach: a expert-based opinion study

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Abstract

We aim to use an expert-based study to identify individual and environmental variables related to runners' performance. Using a Delphi method, we listed authors worldwide based on the topics "running" and "track and field". A total of 12 experts agreed to participate. Information regarding demographic characteristics (e.g., sex, age, the continent of occupation, income characteristics of the country, main occupation) and opinion regarding the individual, environmental and cultural characteristics associated with runner's performance were accessed. Descriptive statistics were performed using absolute values, and thematic analysis. Experts' mean age was 45.7 ± 9.7 years, mainly from Europe (58.3%). For individual variables, training and physiological characteristics were overcited (17.7%). Psychology and genetic aspects were also mentioned (13.3%). For environmental factors, the social, cultural, political, natural, and economic factors were mentioned. Lower importance was attributed to training facilities, built environment, urban design, and historical background. Cultural factors were considered positive factors for most of the participants. Besides the athlete-centred approach (e.g., training, genetic, physiology), social, political, economic, and cultural features were mentioned as important factors to explain the runners' performance. Future studies need to consider these factors to understand deep runners' performance differences.

Keywords: Delphi; Performance; Exercise; Endurance.

Introduction

During the last century, maybe due to the resurrection of the Olympic Games, the interest in maximizing athletes' performance increased among researchers[1]. One of the most traditional, marketed, and watched events in the Olympic Games is the marathon. Besides one of the most important sports, the marathon is also a symbol of resilience and resistance[2], where participation increased among non-professional athletes last years[3]. Leisure, well-being, and a sense of accomplishment are key motives for marathon engagement[4-6] but focus on enhancing performance has also been pointed out as a goal for some runners[4,5,7].

To understand the runners' performance at different competitive levels, an athlete-centred approach has been used[8]. This approach considers the role of morphological (e.g., body mass, body fat percentage, body mass index), training characteristics (e.g., volume and frequency per week, training methods, training intensity distribution), physiological (VO_{2max}, running economy, ventilatory threshold), and biomechanical variables (e.g., step frequency and stride length) as the most important predictors for performance achievement[9,10]. For example, a recent narrative review highlighted 136 independent variables associated with performance in long-distance running[10]. Almost 44% of the variables were related to

aerobic metabolism, while 26% and 20% were associated with training and morphology, respectively[10]. In addition, psychological mood, peer support, running technique, and a lower injury rate are positively related to physical and training performance[11].

Notwithstanding the importance of these variables to modelling runners' performance[10], this dominant conceptual structure is still based on a mechanical point of view that conceives the body as a machine divided into parts, and the performance as the sum of different qualities[12]. Considering that the subject-environment relationship is an open system with constant interactions[13,14], and that running performance emerges from the interaction between variables from different levels[15], a better understanding of running performance/participation demands the use of a holistic approach[15]. Holistic approaches consider the mutuality, and the role of proximal and distal variables situated in different levels, that act together to determine the expression of different outputs[16].

Based on this, recent findings highlighted the role of contextual variables in runners' participation and performance[15,17]. Considering the interplay between the subject, environment, and task, running pacing behaviour has been studied as a complex system[15,17]. That is, beyond the individual variables related to the decision-making, environmental features (i.e., other athletes' behaviour, physical environment barriers)[15] must be considered to explain runners' performance. At the international level, besides the proximal factors (i.e., face-to-face relationships, genetics, training, physiology) related to runners' performance[18], previous studies were developed to understand the African runners' phenomenon[19], considering the role of the lifestyle, physical environment, and cultural factors[20,21]. Similarly, previous studies considered the role of the natural environment (e.g., temperature, wind, barometric pressure)[22,23], social factors (i.e., social support, economic support)[24], and historical background[21,25] as important domains to understand runners' performance. However, few advances were observed in understanding the contextual factors associated with runners' performance.

To further advance our understanding of the contextual factors associated with runners' performance, it is crucial to employ a collaborative approach, ensuring that a range of factors that may have been overlooked in previous studies are considered. It also allows for cross-disciplinary discussions and the integration of different domains of expertise, leading to a more robust and accurate analysis of the factors influencing runners' performance. Therefore, our purpose is to use an expert-based panel study to identify individual and environmental variables considered the most important to runners' performance.

Methods

Study design and panel selection

This is a cross-sectional and exploratory study, in which we used expert's opinions to gain some insights about individual, environmental and cultural factors associated with running performance. The study comprised three different stages, including preparation, conduction, and analysis, as suggested by Beiderbeck[26]. We used open questions to obtain the most important factors to be considered to understand performance in running. The project was approved by the ethics committee in Brazil (Federal University of Sergipe, protocol no 3.558.630). All participants were informed about the research purpose and gave informed consent to participate in the research.

Preparation stage

Panel composition

We used a non-probability purposive sample. The panel composition was based on the list of the top authors worldwide based on the topics "running" and "track and field" on two experts' web pages (https://expertscape.com/ and https://www.scopus.com/). Firstly, we listed the first 100 researchers for each keyword and

excluded those who belong to the first author's research network. Forward, the first 50 authors were invited to take part in the study through email. To deliver a higher diversity in terms of background and geographical location, we invited experts of both sexes, from all continents (i.e., America, Africa, Asia, Europe, and Oceania), and with a Doctorate degree. We did not use any inclusion/exclusion criteria based on their backgrounds (i.e., researchers, entrepreneurs, and physicians were included, for example).

Conduction stage

Data collection procedures

To participate in this study, the participants were invited independently, via e-mail, by the first author (MT). The link to assess the web survey was generated through the Google Forms platform and attached to the invitation email. All participants were asked to complete the survey within three weeks, with a reminder email sent after two weeks. All surveys were completed between May and August 2022, and the participants spent about 15 minutes filling up the survey.

Instrument used for data collection

The first section of the instrument was composed of general instructions, including the theoretical rationale for the study and the purpose. Following, the survey comprised demographic characteristics (i.e., age, sex, economic characteristic of the country of residence, the main occupation in 2022), and a series of open questions regarding the experts' opinion about individual variables (*"In your opinion, taking into account only variables related to the subject (individual variables), which five do you point as the most important to predict runners' performance?"*), environmental variables (*"In your opinion, from the environmental variables, which five do you point as the most important to predict runners' performance?"*), and the influence of culture on running performance (*"In your opinion, countries cultural factors can be related to running performance?*). Experts were asked to support their answers with one or two sentences (*"If your answer is "no", please explain. If your answer is "yes", please describing the priority variables in one or two sentences"*).

All variables mentioned and explanations provided by the experts were independently listed by two authors (MT, TNG). In both domains (i.e., individual and environmental), variables were individually clustered into different categories, considering similarity. Disagreements regarding the variables identified and domains created were resolved through debate. If disagreement persisted, the decision of the senior researcher was considered. For instance, the "physiology" category comprised variables such as "VO_{2max}," "running economy", and "lactate threshold", while the "psychology" category included variables such as "motivation", "mental toughness", and "mental preparation".

Researchers' Feedback and reporting results

Following this, we provided individual reports for each participant of the project. The purpose of this step was to allow the participants to see the big picture, considering the answers from all the participants, as well as to compare their answers with the others. In addition, this procedure also allowed participants to review and, if needed, change their opinions based on the clusters created by the authors. Results reports were made considering both frequency (the number of times the variable/ category was cited) and importance of the variables cited (considering the order in which they were cited). We also considered and discussed experts' statements about each domain.

FIGURE 1 - Summary of the process used in this study.

Data analysis

Participants' descriptive information was presented individually (age, sex, continent of occupation, country economic characteristic, and main occupation in 2022). All variables cited and explanations provided by the experts, were listed independently by two authors (MT and TNG), and disagreements were resolved in debate. Variables for both individual and environmental domains were clustered in different sub-domains. For example, information regarding "$\dot{V}O_{2max}$", "running economy", and "lactate threshold" were clustered in a sub-domain named "physiological". Thematic analysis was performed to identify the main categories cited by participants in their answers. An Excel sheet was used to organize the answers and to perform the analysis.

Results

Of the authors invited to take part in the study, 12 agreed to participate. TABLE 1 presents the experts' descriptive information. Almost all of them are male (91.7%), living in high-income countries, and from the European continent. There were also experts from South America, but no participants from Asia, Africa, or Oceania. Based on information from 2022, most of the participants are professors (66.7%), while few of them self-classified themselves as a researcher.

TABLE 1 - Experts' panel descriptive information.

Code	Sex	Age	Continent of occupation	Country economic characteristic	Main occupation
Expert 1	Male	42	Europe	High- income	Physician
Expert 2	Male	30	South America	Middle-income	Professor
Expert 3	Male	46	South America	Low-income	Professor
Expert 4	Male	63	North America	High- income	Physician
Expert 5	Male	60	Europe	High- income	Professor
Expert 6	Male	35	Europe	Middle-income	Researcher
Expert 7	Male	63	Europe	High- income	Professor
Expert 8	Male	45	South America	Middle-income	Professor
Expert 9	Female	40	Europe	High- income	Professor
Expert 10	Male	37	Europe	High- income	Professor
Expert 11	Male	55	North America	High- income	Entrepreneur
Expert 12	Male	33	Europe	High- income	Professor

Based on information from 2022.

TABLE 2 presents the experts' panel results for both individual and environmental variables. For individual variables, training (training background, frequency) and physiological characteristics ($\dot{V}O_{2max}$, running economic, $v\dot{V}O_{2max}$, lactate threshold) were the most important sub-domains cited. Psychology (motivation, mental toughness) and genetic aspects were also indicated as important factors for performance prediction. Few answers mentioned motor skills/physical fitness (two mentions) and nutrition aspects (one mention). Variables often cited as the most important were clustered among the physiologic group ($\dot{V}O_{2max}$, running economy, peak treadmill speed).

Environmental factors cited included social, cultural, political, and economic factors. The natural environment, namely weather characteristics, was also pointed out as important to runners' performance. Small importance was attributed to facilities, built environment, urban design, and historical background. Variables often cited as the most important were clustered among the group of natural environments (hills, surface, wind, altitude, temperature).

TABLE 2 - Participants' opinions regarding individual and environmental factors associated with runners' performance.

Individual factors	**Absolute Frequency**
Training	8
Physiology/Biomechanical	8
Psychology	6
Biological/genetic/Morphological	6
Motor skills/Physical fitness	2
Nutrition	1
Environmental factors performance-related	**Absolute Frequency**
Social/Cultural/Political/Economic	12
Natural environment/Geographic	8
Facilities/Built Environment/Urban Design	6
Historical background	1

Note: Training characteristics (regularity in training, session frequency, training experience); Physiology ($\dot{V}O_{2max}$, Running Economy, Capacity to maintain $\dot{V}O_{2max}$, running economy, vertical stiffness, velocity associated with $\dot{V}O_{2max}$, elastic mechanism (landing-takeoff asymmetries), Peak treadmill speed, lactate threshold, Maximal sustainable fraction of $\dot{V}O_{2max}$); Psychology (motivation, mental toughness, Mental attitude, mental preparation); Biological/genetic/Morphological (Age); Motor skills/physical fitness (lower limb strength, cardiorespiratory fitness); Nutrition (nutritional adjusts before and during the race); Social/cultural/politic/economic (motivational environmental people, type of food in the locality, coach, team, health professionals, adequate diet, lifestyle, organizational aspects of elite sports in the country); Natural environment/Geographic (Climatic and weather aspects, air quality, hills, surface, temperature, humidity, atmospheric pressure, concentrations of atmospheric pollutants, living at high altitude, Altitude, Gradient, Temperature/Humidity/Solar conditions/Wind); Facilities/Built Environment/Urban design (Proper equipment, Footwear, close location for training living working); Historical background (connection of the group of individuals with this space throughout history).

Participants explained their answers regarding the main factors associated with the runners' performance. For individual characteristics, most of the experts highlighted the role of genetic, physiological/biomechanical, and biological characteristics, without overlooking the interpersonal variability and multidimensional characteristics of the performance. The specificity of predictors was also mentioned, meaning that factors associated with performance in short distances (i.e., 5km, 10km) could differ from those in long-distance running performance (i.e., half-marathon and marathon). Variables such as sex, age, and morphological characteristics were overcited. However, besides the individual aspects, the disposition for training, and motivation were considered important characteristics. Psychological attributes were mentioned as factors related to training maintenance, sports pressure, and motivation to training commitment. In addition, it was also cited the possibility of transposing the training, if the biology is favorable.

> "The physical characteristics are of importance, but the time and motivation to train are also very important…" (Expert 1).

Regarding environmental features, three different approaches were considered: (1) those related to athletes' day-life; (2) the social, economic, and

political environment; and (3) the geographical/natural environment. The athlete's day-life comprise the closest environment where the athlete is inserted, such as the family, sports team, coach, and health professionals' support. The proximal environment was considered responsible for the encouragement, and emotional and career support. In general, social, economic, and political characteristics, as well as the organizational aspects of elite sports in the country were also reported. Moreover, hills, temperature, humidity, atmospheric pressure (altitude), and concentration of atmospheric pollutants were mentioned. These factors are directly or indirectly related to the environment where athletes live/train and can act in the expression of the performance.

> 'The connection of the human being in a certain environment (space) throughout long-term history are fundamental elements for sports development" (Expert 3).

In addition, the role of cultural factors in explaining runners' performance was mentioned. Most of the participants mentioned the positive influence of cultural characteristics, in addition to the financial support from the government. Social norms, values of sports in society, stereotypes, acceptance that women have a sports career, and childcare availability were related to between-countries differences regarding cultural aspects. Another participant added that although instability is likely to hinder an athlete's performance, a supportive nation or media environment is positively related to athletes' behaviour, and the possibility of performance increases.

> "Cultural issues are very important, as they show that the sporting success of a locality is not only linked to the financial and structural aspect. Several modalities show that different cultural factors influence this process…" (Expert 3).

Discussion

We used a panel of experts to identify individual and environmental variables considered most important to runners' performance. Our main findings highlighted that, beyond individual attributes, social, economic, political, and historical factors were considered important. Below, we summarize the ten primary domains cited (FIGURE 2).

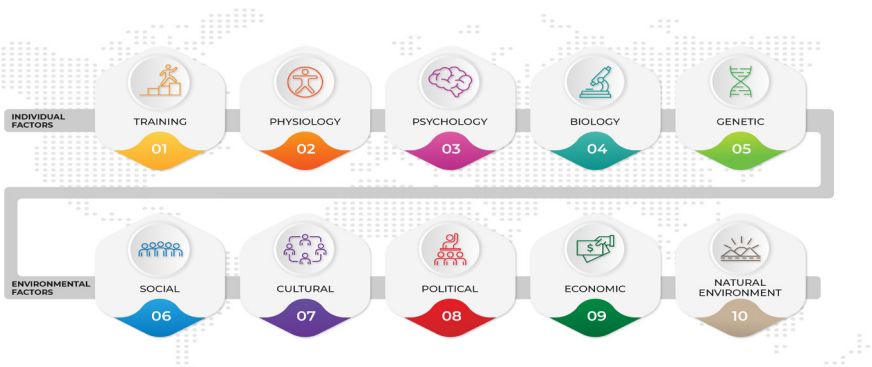

FIGURE 2 - The ten most important individual and environmental factors related to runners' performance, according to the experts' opinions. Variables are ranked according to importance for individual (one to five) and environmental (six to 10).

Individual variables

The first results highlight the influence of training and physiological domains as important factors in predicting runners' performance. These results were expected, as previous literature support the role of both domains in runners' performance[10,27]. The background and load of training were previously mentioned as predictors for runners competing in different distance events[10,28], and competitive levels[27,29]. In this study, competition distance were not

specified (e.g., 5 km, 10 km, half-marathon, marathon), but the relevance of training variables for endurance performance includes similar functional changes (biomechanical, biochemistry, bioenergetic), that enhance fatigue resistance[30] in various race events.

Motivation was considered the most important psychological factor. Athletes' motivation acts as catalyst for performance, as internally motivated athletes show higher training engagement (i.e., training volume and frequency, running experience, participation in competition)[31,32], which can be related to functional adaptations, such as physiological and morphological changes. In this sense, motivation acts as a primary trigger for a series of performance-related behaviours. Previous studies showed that motivation varies significantly based on sample characteristics[4-6]. Higher scores for body weight, affiliation, psychological coping, life meaning, and self-esteem were shown among women, while men presented higher values for competition[33]. Considering race distance, athletes competing in the ultramarathon, presented higher scores on affiliation and life meaning, and lower values for body weight concern, personal goal achievement, and self-esteem[33,34]. Despite the research on runners' motivation, there is limited evidence on the magnitude of motivation effect on runners' engagement and performance.

The biological, morphological, and genetic factors cited included age, sex, body fat, body mass index, and specific genes. Performance differences between sexes have been investigated for different distances and events[35,36]. Men perform better at all distances, with a sex-performance gap of about 10%[35,36]. Sex differences are explained by physiological differences (e.g., $\dot{V}O_{2max}$ is about 10% lower in female athletes)[37], social influences (e.g., social pressure, financial and emotional support), and anthropometric characteristics (e.g. muscle mass, body fat, skin-fold thicknesses, upper arm circumference)[38]. Morphological variables affect running performance since the energy required to transport body weight is the most important economic cost during a race, meaning heavier runners tend to spend more energy[39]. Additionally, stride length, movement stability, and ground and air resistance were strongly associated with endurance performance via running economy[40].

Regarding genetic characteristics, studies have highlighted the role of specific polymorphism in endurance performance, influencing anthropometry, physiological function, and training adaptation[41,42]. A total of 14 genes, with 16 potential single nucleotide polymorphisms were associated with marathoners' performance[43]. Similarly, anthropometry, circulatory and respiratory systems, energy metabolism and calcium homeostasis were associated with gene characteristics in two different East African ethnicities[41]. While discussing specific genes and their impact on runners' is beyond the scope of this study, additional information is available in the literature[41-43].

Environmental variables

For environmental characteristics, responses were categorized into social, economic, political, and geographical/natural factors. Despite the importance of understanding environmental influences on runners' performance, few studies have been conducted to explain and predict these effect[44,45]. Some studies have focused on East African runners, showing that Kenyan and Ethiopian runners engage in running as a path to social and economic empowerment, coupled with a "legacy of excellence" that connects today's elite runners to their legendary predecessors and a distinct ethnic and environmental background contrasted to the general population[18,19]. Additionally, athletes from the Kalenjin and Arsi tribes have been reported to produce the best runners in Kenya and Ethiopia, respectively, due to living and training at high altitudes and the habit of running to school as children both as a sporting activity and as the primary method of transport to and from school[18].

The natural environment includes hills, temperature, humidity, atmospheric pressure (altitude), and levels of atmospheric pollutants. Higher temperatures slowed down marathoners, with a higher effect on non-elite marathoners[46]. This evidence was shown among athletes competing in different race events, such as Berlin Marathon and New York City Marathon[22,46]. As a practice performed in an outdoor context, the effect of atmospheric pollutants as a performance-related factor

needs to be considered. Evidence is available regarding the role of atmospheric pollutants in health outcomes[47], and as a constraint to runners' performance[48]; however, no information is available about the influence on training commitment.

Training facilities, built environment, and urban design were also considered important. Although running is considered a low-cost activity, few studies address the influence of the built environment on runners' performance[44]. Regarding the role of cultural characteristics, social norms, the value of sports in society, stereotypes, and the men's and women's roles within a society were considered. These variables are associated with the overrepresentation of certain countries in specific events. For instance, Nikolaidis et al[49] reported that Kenyan and Ethiopian professional runners have dominated performances in the 10-km, half-marathon, and marathon, while Japan and Russia are most represented in the 100-km event. Meanwhile, countries like Spain, Russia, Switzerland, and Ukraine have produced outstanding recreational runners internationally[3]. Although these factors have been highlighted, the mechanisms explaining the link between culture and runners' performance are not well established. Future studies should advance ecological and cross-cultural research using mixed methods to better understand these associations.

Limitations and Strengths

This study is not free of limitations. Firstly, a limitation that impair the generalization of the findings was the lack of specificity regarding the running distance (e.g., 5 km, 10 km, half-marathon, marathon). It is well known that short- and long-distance running events have distinct physiological demands and training requirements. However, our goal was to provide a general perspective on individual and environmental factors that could influence endurance activities. Future studies may build on this initial approach to investigating these factors in relation to specific race distances. Secondly, the potential for misunderstanding specific terms, such as culture, and social and political factors should be acknowledged. Thirdly, participants bias must also be considered. Despite our approach of including participants from diverse backgrounds, only those interested in these research topics were likely to fill up the surveys. While other study designs may offer higher levels of evidence, expert opinions have been utilized in scientific literature[50], and are valuable in drawing significant conclusions and guiding future research. Future studies can consider the inclusion of coaches' or runners' opinions and verify if they are according to the results of the present study. In addition, it is appropriate to develop studies considering differences between elite athletes and amateur runners, since the prioritized variables are different. The practical application of the present study includes synergic work involving stakeholders, coaches, and runners to provide a better environment for to runners be engaged in training.

Conclusion

Beyond the athlete-centred approach (training, genetic, physiology), social, political, economic, and cultural factors were also identified as important in explaining runners' performance. The key factors identified can help inform future studies to consider the complex relationship between environmental and individual factors, and how runners' performance emerges from these interactions. Additionally, future studies need to explore the underlying mechanisms that connect the environment and athletes' performance.

Resumo

Compreensão de fatores relacionados à performance em corredores através de uma abordagem holística: um estudo de opinião baseado em especialistas.

Nosso objetivo foi utilizar um estudo baseado na opinião de especialistas para identificar variáveis individuais e ambientais relacionadas ao desempenho de corredores. Utilizando o método Delphi, listamos os principais autores com base nos tópicos "corrida" e "atletismo" a nível mundial, sendo que um total de 12 especialistas concordou em participar. Foram coletadas informações sobre características demográficas (como sexo, idade, continente de atuação, características econômicas do país e ocupação principal) e opiniões sobre as características individuais, ambientais e culturais associadas ao desempenho de corredores. Análises descritivas e temática foram utilizadas. A média de idade dos especialistas foi de 45,7 ± 9,7 anos, sendo a maioria da Europa (58,3%). Em relação às variáveis individuais, as características de treinamento e fisiológicas foram as mais citadas (17,7%), seguido de aspectos psicológicos e genéticos (13,3%). Entre os fatores ambientais, destacaram-se os fatores sociais, culturais, políticos, naturais e econômicos. Menor importância foi atribuída às instalações de treinamento, ao ambiente construído, ao design urbano e ao contexto histórico. Fatores culturais foram considerados positivos pela maioria dos participantes. Além da abordagem centrada no atleta (por exemplo: treinamento, genética, fisiologia), características sociais, políticas, econômicas e culturais foram apontadas como importantes para o desempenho dos corredores. Estudos futuros precisam considerar esses fatores para compreender melhor as diferenças de desempenho entre corredores.

Palavras-chave: Delphi; Performance; Exercício; Resistência.

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