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Measuring power, force, velocity, and mechanical effectiveness in Football: Theoretical Considerations

Medição da potência, força, velocidade e eficácia mecânica no Futebol: Considerações teóricas

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TITULO DO ARTIGO

Medição de potência, força, velocidade e eficácia mecânica no Futebol: Considerações teóricas

RESUMO

Os perfis potência-força-velocidade no futebol podem ser avaliados pelas fórmulas de Samozino, de modo a determinar a velocidade máxima teórica (V_0), a força máxima teórica (F_0), a potencia máxima teórica (P_{max}), o perfil força velocidade (F-V) (inclinação da relação F-V, Sfv), a razão de força (RFmax) e o índice da técnica de aplicação de força (DRF). A presente revisão crítica pretende esmiuçar os procedimentos teóricos e metodológicos para mensurar a potência, a força, a velocidade e a eficácia mecânica no Futebol.

Concluiu-se que o método de Samozino é sensível, prático e económico para medir a relação F-V e a eficácia mecânica no Futebol. Assim, esta abordagem metodológica deve ser considerada nas estratégias de campo para a avaliação e monitorização de jogadores de futebol.

As futuras investigações devem considerar igualmente os diferentes níveis competitivos, concretamente os contextos elite, subelite e amadores, aportando novas evidências para a mensuração da potência, força, velocidade e eficácia mecânica em contextos de futebol masculino, feminino e juvenil.

Palavras-chave: força e condicionamento, avaliação, velocidade, força, poder futebolístico.

TITLE PAPER

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ABSTRACT

Power-force-velocity profiles in football can be assessed by Samozino's formulas to determine theoretical maximal velocity (V_0), theoretical horizontal force (F_0), horizontal power (P_{max}) and force-velocity (F-V) profile (i.e., the slope of the F-V relationship; Sfv), ratio of force (RF_{max}) and index of force application technique (DRF). Current critical review aims to explain the theoretical and methodological procedures for measuring power, force, velocity, and mechanical effectiveness in Football.

In conclusion, Samozino's method is sensitive, straightforward, and cost-effective for measuring F-V relationship and mechanical effectiveness in Football. Therefore, this methodological approach should be considered in field-based assessment and monitoring strategy of the football players.

Future research should also include different competitive level such as elite, sub-elite and recreational for measuring power, force, velocity, and mechanical effectiveness in male, female, and youth football environments.

Keywords: Strength and conditioning, assessment, speed, strength, power football.

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INTRODUCTION

Sprint mechanical force-velocity (F-V) profile characterize limits of the neuromuscular system to produce maximal levels of force, velocity, and power (Cross et al., 2017). Power directly depends on both force and velocity (Jiménez-Reyes et al., 2019; Marcote-Pequeño et al., 2018). Also, mechanical effectiveness in force application can be assess during sprint running (Osgnach et al., 2010; Prampero & Osgnach, 2018). Athlete evaluation of the training and competition can be conducted periodically or continuously (Clemente et al., 2014). If the assessment aims to identify a specific moment and analyse the athlete's state or condition, we will be controlling in a periodic way (i.e., assessment) (Branquinho, Ferraz, Duarte-Mendes, et al., 2020; Silva et al., 2022). If the control aims to provide regular information on the athlete's psychophysiological response to training stimulus, then the daily character will assume the concept of continuous (i.e., monitoring) (Oliveira et al., 2019; Teixeira et al., 2021a). However, the literature exposes a lack of consensus on the most effective monitoring strategies to for athletic monitoring and evaluation (Miguel et al., 2021; Teixeira et al., 2021b). In training, it is mainstream to reports the work rate (Carling et al., 2008; O'Donoghue, 2004), workload (Gabbett et al., 2017; Nobari, Arslan, et al., 2022) and training load (Impellizzeri et al., 2005; Vanrenterghem et al., 2017). When analyzing match load, different concepts has been developed such as physical performance (Bradley & Ade, 2018; Coutinho et al., 2018; Gonçalves et al., 2018), activity profile (Aquino et al., 2020; Nobari, Fani, Clemente, et al., 2021) and match running performance (Fernandes et al., 2022; Teixeira et al., 2021c; Vieira et al., 2019). Power-force-velocity profiling during sprint running can compiled these methodological approaches with a high practical applicability (Cross et al., 2017).

In Football, sprinting, accelerations, decelerations, body impacts and change-of-direction are key performance factors (Oliveira et al., 2022; Oliveira & Rico-González, 2021). In fact, football is characterized by intermittence within high demanding movements and rest periods with low intensity (Bangsbo, 1994; Stølen et al., 2005). Regardless of the athlete assessment and monitoring strategy, it is important to quantify the physical and physiological demands behind the technical and tactical actions that are most important for match performance (Ferraz et al., 2018, 2020; Teixeira et al., 2022a,2022b). Straight sprint and vertical jumps have reported as the two most frequent actions in football and futsal competitive matches (Bradley et al., 2016; Faude et al., 2012). Also, a tier-specific evolution of match performance characteristics has been reported, specifically in the high intensity demands (Bradley et al., 2016).

Consequently, force-power-velocity relationships and mechanical effectiveness of force application have been recently used to analyse in sprint profiles (Morin et al., 2011; Morin & Samozino, 2015; Samozino et al., 2016). In this sense, Samozino et al. (2016) have proposed a straightforward method, convenient for field assessment, to determine theoretical maximal velocity (V_0), theoretical horizontal force (F_0), horizontal power (Pmax) and F-V profile (i.e., the slope of the F-V relationship; Sfv). Ratio of force (RF_{max}) and index of force application technique (DRF). Power-force-velocity profiles in football codes was analysed previously as a sensitive method (Manson et al., 2021; Marcote-Pequeño et al., 2018; Simperingham et al., 2016; Sweeting et al., 2017). Specifically, in football and futsal have been showing differences in power-force-velocity variables on sprint and jump performance (Devismes et al., 2019; Jiménez-Reyes et al., 2019; Manson et al., 2021; Marcote-Pequeño et al., 2018). Also, an influence has been reported amongst sprint mechanical and F-V profiles, according to sex, competitive levels, and various sports (Jiménez-Reyes et al., 2018, 2019). It is suggested that trained futsal players have a higher F_0 and lower V_0 than football players. Pmax, Sfv and DRF is similar for both sports (Jiménez-Reyes et al., 2019; Marcote-Pequeño et al., 2018). Recently, Teixeira et al. (2021d) showed that the sprint mechanical F-V profile can distinguish between sexes in overall enhanced in elite football teams.

Thus, this critical review aims to explain the theoretical and methodological procedures for measuring power, force, velocity, and mechanical effectiveness in Football.

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THEORETICAL CONSIDERATIONS

External mechanical limits of the neuromuscular system during the specific multijoint movements was expresses by F_0 and v_0 that the system can develop, and with which is associated the maximal power output (P_{max}) (Morin & Samozino, 2015; Samozino et al., 2016). Mechanical effectiveness in force application was assessed by DRF and RF_{max} during sprint running (Samozino et al., 2016). Better values express better performance (Seifert et al., 2014). The following theoretical considerations procedures for measuring power, force, velocity, and mechanical effectiveness in Football was based fundamentally Samozino's equations and precedent (Gaudino et al., 2013; Morin et al., 2011; Morin & Samozino, 2015; Osgnach et al., 2010; Prampero et al., 2005; Prampero & Osgnach, 2018; Samozino et al., 2016, 2021).

Theoretical maximal force (F_0)

F_0 is the the maximal force that the runner is able to produce the higher values (Samozino et al., 2016, 2021). Horizontal antero-posterior ground reaction force (GRF) (F_H) is applied to the body centre masse (CM) modelled over time as:

$$F_H(t) = m \cdot a_H(t) + F_{aero}(t)\ [Eq. 1]$$

where *m* is the football player's body mass (in kg) and F_{aero} (t) is the aerodynamic drag to overcome during sprint running that is proportional to the square of the velocity of air.

Mean net vertical GRF (F_V) was applied in the body CM over each full step modelled over time as equal to body weight (Prampero et al., 2005):

$$F_v(t) = m \cdot g\ [Eq. 2]$$

where g is the gravitational acceleration (9.81 m/s ^{2}).

Theoretical maximal speed (V_0)

During a running maximal acceleration, horizontal velocity (v_H), the time (*t*) curve has been expressed by a mono-exponential function (Morin et al., 2011; Morin & Samozino, 2015):

$$v_H = v_H \cdot (1 - e^{-\frac{t}{\tau}})\ [Eq. 3]$$

Where v_H – maximal speed at the end of the acceleration (m · s $^{-1}$), e is Euler´s number (i.e., 2.71828 in the t, time (s), and τ (named as tau) is acceleration time constant.

Maximal power output (P_{max})

P_{max} is the maximal power that the football player is able to deliver. P_{max} can be calculated as the apex of the P–V relationship, expressing the first mathematical derivation of the associated quadratic equation (Samozino et al., 2016):

$$P_{max} = \frac{F_0 \cdot v_0}{4}\ [Eq. 4]$$

Where, and in agreement with Samozino's formulas, P_{max} is the maximal power output (W), F0 is maximal horizontal external force (N) and v0 is the maximal velocity (m/s).

According to Osgnach et al. (2010), energy cost and metabolic power can be calculated by a Equivalent estimation (P_{met}) (High power: 20-35 W· kg $^{-1}$; elevated power: 35-55 W · kg $^{-1}$; low power: >55 W · kg $^{-1}$).

Slope of the F-V relationship (Sfv)

Moreover, the slope of the F–V relationship determines the F–V mechanical profile (SFV), expressing the individual ratio between force and velocity qualities (Morin et al., 2011; Morin & Samozino, 2015; Samozino et al., 2016). Samozino's original proposal the F–V and P–V relationships from the mechanical properties obtained from multijoint movements (acyclic or cyclic) integrated in the different complex mechanisms involved for total external force (Samozino et al., 2016).

Ratio of force (RF_{max}) and index of force application technique (DRF)

RF_{max} is the is the ratio between the horizontal external force and the resultant GRF, expressing the balance between force delivered and velocity achieved (Samozino et al., 2016). RF_{max} express the mechanical effectiveness in sprint running. A larger radius means a higher

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mechanical effectiveness (Prampero et al., 2005).

RF_{max} can be quantified over each support phase or step by the ratio (RF_{max}) to the corresponding total resultant GRF (F_{Res}), expressing the acceleration phase by the slope of the linear decrease in RF_{max} when velocity increases (Samozino et al., 2016):

$$RF_{max} = \frac{F_H}{F_{Res}} = \frac{F_H}{\sqrt{{F_H}^2 + {F_v}^2}} \ [Eq. 5]$$

Where, ratio between RF_{max} is the resultant GRF, F_v is the vertical external force (N) and F_H is the horizontal external force (N).

DRF is the ratio of the net horizontal and GRF sprinter´s ability to keep a forward horizontal orientation of the resultant GRF vector. RF_{max} and DRF can be reasonably computed from FH and FV values modeled for t > 0.3 s (Prampero et al., 2005; Samozino et al., 2016, 2021)

CRITICISMS

Although Samozino's formulas are a sensitive method for assessing the neuromuscular capacities to produce maximal levels of force, velocity, power, and mechanical effectiveness in force application during sprint running, the gold-standard are the force plates in tandem. However, the reliability and validity are well reported in the literature (Ahmad & Barbosa, 2019; Silva et al., 2021). Pioneering Osgnach's approach determines that high-intensity movements expressed as high-power output are two to three times larger than those based only on running speed (Osgnach et al., 2010). Gaudino et al. (2013) defends argues that metabolic power may provide better examination for high-intensity component of training which typically represents the most physically demanding elements. Thus, measuring the metabolic power analysis can minimize underestimation on external load quantification using traditional monitoring approach based on distance and speed thresholds (Teixeira et al., 2021e). Acceleration outputs, metabolic power and body impacts have been poorly integrated with positional data (Teixeira et al., 2022b). Behavioural data should still be better contextualised and the related-bias for physiological thresholds must be considered upon the time-dependent and transient reduction (Barrera et al., 2021; Miguel et al., 2022; Teixeira et al., 2021a). Pacing behavior, decision-making, self-regulation of effort, prior knowledge of the duration of the task, and perception of effort should also be considered in the athlete monitoring and assessment (Branquinho et al., 2021; Branquinho et al., 2020; Ferraz et al., 2022; Ferraz et al., 2018b; Ferraz et al., 2018c). In youth foboall, the relative age, maturity state and stage of development should be considered when interpreting current findings (Arede et al., 2021; Coutinho et al., 2020; Teixeira et al., 2022b). Including well-being and readiness considerations is another possible path for measuring power, force, velocity, and mechanical effectiveness in football (Costa et al., 2019; Nobari et al., 2021; Nobari et al., 2022; Oliveira et al., 2022). Future research should include different competitive level such as elite, sub-elite and recreational in male, female and youth football environments (Teixeira et al., 2021e).

Conclusions

Samozino's method is sensitive, straightforward, and cost-effective method for measuring power, force, velocity, and mechanical effectiveness in Football. This methodological approach should be considered in field-based assessment and monitoring strategy of the football players.

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