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Original Article

Neuromuscular indices associated with 200- and 400-m sprint running performance

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Abstract: The purpose of this study was to investigate the relationship between the neuromuscular indices with the 200- and 400-m sprint running performance. Fourteen federated sprinters took part in this study. The athletes performed the SJ, CMJ and CJ_{15s} vertical jumps on a force platform to obtain the jump height variable. In addition, performance time in 20-m sprints and simulated 200- and 400-m races were measured. Multiple regression analyses (5% of significance) were used to determine variables associated with performance in the 200 m (P200) and 400 m (P400). Two models were generated to explain P200: the first to explain 56% of the P200 variability, using the variable CMJ alone; and the second to explain 68%, using the variables CMJ and $sprints_{20m}$. None of the neuromuscular variables analyzed were associated with performance in the 400 m. Therefore, we concluded that CMJ, which involves the elastic energy stored during the stretch-shortening cycle, is the main variable to predict P200.

Key Words: Performance. Sprinters. Muscle Power.

Índices neuromusculares associados com a performance de corredores velocistas em provas de 200 e 400 m rasos

Resumo: O objetivo deste estudo foi investigar as relações entre índices neuromusculares com a performance de corredores nas provas de 200 e 400 m. Quatorze velocistas federados fizeram parte deste estudo. Os atletas realizaram os saltos CMJ, SJ e CJ15s sobre uma plataforma de força, obtendo-se a variável altura de salto. Posteriormente, foi mensurado o tempo em sprints de 20 m e na simulação das provas de 200 e 400 m rasos. Utilizou-se análise de regressão múltipla (5% de significância) para determinar as variáveis preditoras da performance nos 200 (P200) e 400 m (P400). Dois modelos foram usados para predizer a P200: o primeiro explicando 56% da variabilidade da P200, usando somente a variável CMJ; e o segundo para explicar 68%, usando as variáveis CMJ e sprints20m. Nenhuma das variáveis neuromusculares analisadas explicaram a P400. Assim, concluí-se que o CMJ, que envolve energia elástica armazenada durante o ciclo alongamento-encurtamento, é a principal variável preditora da P200.

Palavras-chave: Performance. Velocistas. Potência muscular.

Introduction

Many factors may influence performance in speed races, in particular, the athletes' level of muscle power is considered critical for these high-intensity sport events (HENNESSY; KILTY, 2001; HARRINSON et al., 2004; SMIRNIOTOU et al., 2008). The current literature recognizes that high levels of power output is dependent on neuromuscular factors, as well as the athlete's capacity for neural recruitment and usage of the elastic energy (BOSCO et al., 1981; VIITASALO; BOSCO, 1982; KOMI, 2000; MERO et al., 2001) in addition to the rate of anaerobic energy release (GASTIN, 2001).

A number of testes have been used in order to measure muscle power in an attempt to predict sprint times, being the vertical jumps one of the more valid technique for such measurements (MARKOVIC et al., 2004). In the squat jump (SJ) protocol, power is measured by considering only the concentric phase of the movement, which reflects the athlete's capacity of neural recruitment (BOSCO, 1999). The performance in SJ shows correlation with short sprints (r = -0,68), since in both situations the concentric action of the knee extensors acts as a determinant factor in propulsive force generation (SLEIVERT; TAINGAHUE, 2004). This propulsive force is extremely important to the sprinter's acceleration, especially at take-off from the starting block as well as during the initial acceleration phase of the running (MERO et al., 1992).

The Counter Movement Jump (CMJ), as well as the SJ, is considered an excellent indicator of the power of the lower limbs. However, the power output in the CMJ is conditioned by the athlete's ability to release the accumulated elastic energy during the stretching-shortening cycle (SSC). The latter phenomenon is due to a preceded eccentric action of a concentric muscular action (KOMI, 2000). Reports in the literature have suggested that this mechanism results in increased muscle power (BOSCO et al., 1981; KOMI; GOLLHOFER, 1997) and is considered an important factor in sprinting performance (KUBO et al., 2000; MERO et al., 2001; HARRISON et al., 2004).

In addition to neuromuscular factors, muscle power is dependent on the metabolic system that sustains muscle function in short-distance high-intensity events (GASTIN, 2001). This capacity has been considered of great significance for the performance in sprint races (MIGUEL; REIS, 2004). For an estimation of both systems (neuromuscular and metabolic), continuous jump (CJ) assesses the athlete’s capacity of maintaining maximal power over a certain period of time (BOSCO, 1999).

Previous studies have reported relationship between the indices CMJ and SJ with the performance in short running events as the 100 m (HENNESSY; KILTY, 2001; SMIRNIOTOU et al., 2008). However, in speed-endurance events as the 400 m, there are different characteristics regarding to the strategy and effort applied over the race (VITTORI, 1995). According to Miguel and Reis (2004), the CMJ is related with the 400-m sprint running performance, but only when a large variability of performance is present in the group of athletes.

Thus, in the present study we investigated whether the neuromuscular indices (SJ, CMJ, CJ_{15s} and $sprint_{20m}$) can predict, through a multiple regression, the performance in races of different characteristics and distances (200- and 400-m) in a homogeneous group of sprinters.

Methods

Athletes

Fourteen federated sprinters in regular training for at least three years at a regional and national competitive level participated in the present study (all males; age = 20.89 ± 3.23 years; weight = 69.77 ± 5.93 kg; height = 176.93 ± 7.21 cm; and body fat = 8.32 ± 1.67%). The athletes ranked among the 20 best sprint times in the 200 (22 – 24,8 s) and 400 m (49,6 – 54,7 s), according to data from the Track and Field Federation of the State of Santa Catarina, Brazil, were selected for the study. The purpose of the study and the testing procedures were explained to the participants, who signed an inform consent prior to testing. This study was approved by the Committee on Research involving Human Subjects of the Federal University of Santa Catarina, Brazil (number 319/07).

Testing procedures

Tests were performed over a 3-day period, as follows: first day: anthropometric measures (body weight, height and skinfolds) according Petroski (2007) and time trial in the 200- and 400-m races at maximal intensity (to determine running performance); second day: vertical jump session; and third day: 20-meter sprints. All athletes were assessed during competitive season and instructed not to perform any high-intensity training 48 h prior to the assessments.

Performance assessment

The athletes performed a time trial run in 200-m and 400-m distances, in this order, at maximal intensity, on a 400-m official track. The races were separated by a 4-hour rest period, sufficient to ensure the recovery of energy sources (BOGDANIS et al., 1998), beyond to consider the ecological validity of tests. A manual chronometer was used to record the time.

Vertical jumps (SJ, CMJ and CJ)

Jump height was measured using the vertical jump protocols developed by Bosco (1999), which have 0.94 and 0.97, for the reliability and specificity, respectively. All jumps were performed on a Kistler Quattro Jump piezoelectric force platform (Type 9290AD; Kistler Instrument AG, Winterthur, Switzerland), which can assess the applied vertical force.

The SJ was the first jump performed: the athlete started from a stationary semi-squatted position, with an approximately 90º knee angle, the back as straight as possible, and hands on the hips. A successful trial was one where no countermovement prior to the jump execution was observed. The second protocol consisted on the execution of a CMJ: the athlete started from a standing position, with hands on the hips, and then jumped as high as possible after a countermovement, which consisted in lowering the body center of gravity as quickly as possible, with an approximately 90º knee angle, tight muscles stretched and eccentrically activated before the concentric contraction. In the last protocol, a continuous jump sequence was performed (CJ_{15s}), in which the athlete was instructed to perform as many jumps as possible for a 15-s period without interruption. The purpose of this test was to assess the capacity of the metabolic system that sustains muscle activity during this high-intensity effort (BOSCO, 1999). Similar to the previous jumps, the athlete jumped with hands on the hips and the back as straight as possible. Knees were controlled to hold a position as close as possible to a 90º knee angle in the descending phase of the jump.

The participants were given three attempts for the SJ and CMJ, separated by a 1-min rest period, whereas for the CJ_{15s} participants were given only one attempt, since this test leads to exhaustion and can generate fatigue. The best of the three SJ and CMJ trials were use in the analyses. The vertical force measured by the platform in the three different jumps was used to calculate the elevation of the body's center of gravity (h) by means of double integration, according to the equation:

$$h = \text{int}\,(V(t) - Vo)\,dt$$

where: h = height; V = final velocity; V_0 = initial velocity; dt = derivation in the time

Sprint assessment

The athletes performed, on a racing track, three maximal 20-m sprints with a flying start, i.e., the runners had 15 m to accelerate before crossing the 20-m starting line (NUMELLA et al., 2006). To record the time, two Speed Test 4.0 electronic photocells (CEFISE, São Paulo, Brazil), connected to an electronic timer were used. The athletes wore track spike shoes and completed an individual warm-up prior to testing. The fastest trial among the three attempts was selected for the data analyses.

Statistical analysis

The Shapiro-Wilk test was used to check the assumption of normal distribution. Descriptive statistics (average, standard deviation and variation coefficient) were used to present the variables of the study. Multiple regression analysis, with stepwise method for including of independent variables (SJ, CMJ, CJ_{15s} and $sprint_{20m}$), was used to determine the best indices to explain P200 and P400. The level of significance was set at 5%. The Statistical Package for the Social Sciences (SPSS™) version [11.5] for Windows™ was used for data analyses.

Results

Descriptive analyses (mean values, standard deviation and variation coefficient) of the variables (SJ, CMJ, CJ_{15s}, $sprint_{20m}$, P200 and P400) are shown in Table 1.

Table 1. Descriptive values of the neuromuscular variables and 200 and 400-m time performance.

	Average	**SD**	**VC (%)**
SJ (cm)	48,94	5,45	11,14
CMJ (cm)	52,51	5,97	11,36
CJ (cm)	46,37	4,59	9,90
$Sprints_{20\ m}$ (s)	2,191	0,08	3,63
200 m (s)	23,45	0,77	3,30
400 m (s)	52,77	1,89	3,59

SJ= Squat Jump; CMJ= Counter Movement Jump; CJ= Continuous Jump

In the table 2, two models were select for explain the P200. According to the regression model, CMJ is the main predictor variable for the 200-m performance, explaining by itself 56% of the variance on P200 (Table 2, Model 1). The inclusion of the variable $sprint_{20m}$ increased the explanation of the P200 to 68% (Table 2, Model 2). There was no significant relation of the indices SJ, CMJ, CJ_{15s} and $sprint_{20m}$ with the P400, therefore, no regression models were fitted.

Table 2. Description of the regression models for the 200-m sprint running performance.

	Regression Models	R^2
1	P200 = 28,67 – 0,10 (CMJ) + 0,53	0,56*
2	P200 = 18,23 – 0,07 (CMJ) + 3,96 (sprints$_{20m}$) + 0,51	0,68*

P200 = 200-m sprint running performance; CMJ = Counter Movement Jump

* level of significance at p<0,05

Discussion

The main finding of this study is that the neuromuscular index CMJ, alone or in association with the neuromuscular variable sprint$_{20m}$, can predict only the 200-m sprint running performance.

The relationships between these neuromuscular indices with sprinting performance has been reported in previous studies (HENESSY; KILTY, 2001; SMIRNIOTOU et al., 2008), in which correlations between CMJ with the 100-m sprint running performance were observed, similarly to what was found in this study in P200. These results indicate that the latter neuromuscular index is significantly related and can predict performance in the short speed races (100 - and 200 m). This can be explained by the fact that in these races, it is fundamental to obtain and maintain maximum or near maximum speeds throughout the race (VITTORI, 1995), which will be facilitated by the high level of muscle power, allowing the sprinter to conduct a high stride rate and move in the shortest possible time towards the finishing line.

The variable CMJ is considered one of the best indicators of the power of the lower limbs (BOSCO et al., 1982). The power generated in this jump will be conditioned by the athlete's ability in using the accumulated elastic energy during the stretching-shortening cycle (SSC). Considering that the CMJ is the main predictor of P200, it seems evident that the SSC is an important mechanism for the 200-m sprint running performance. According to Markovic et al. (2007), as positive acceleration decreases, the running speed is maintained mainly due to the elastic energy stored in the SSC.

Efficient use of the SSC depends on both muscle and neural properties. Regarding these aspects, the influence of the elastic component is an important factor for muscular function in the SSC and consequently to the sprinting performance. This conclusion was drawn from a study in which the extent of the stretch of the sprinter's tendon and its influence in sprint racing performance were assessed by ultrasonography (KUBO et al., 2000). The results indicated that, in peak power production, the elasticity of the tendon structures of the vastus lateralis and gastrocnemius muscles is associated with elastic energy storage and with the subsequent use of this energy during exercise, such as running, that involves the SSC. According to Finni et al. (2000), in order to produce an efficient SSC, an active muscle stretch action is necessary, since there are conditions to support high tensions and to stretch the tendon for elastic energy storage.

In addition to muscle-elastic mechanisms, the role of the stretch reflex has been related to enhancement of the SSC. According to Komi and Gollhofer (1997), an efficient SSC requires three basic conditions: well-timed muscle pre-activation (prior to the eccentric phase), short eccentric phase duration, and an immediate transition between eccentric and concentric phases. Furthermore, during muscle stretch, stretch-induced reflex may play an important role in force-generating coupling of cross-bridges due to reduced muscle stiffness (BOBBERT; CASIUS, 2005; NIKOL; KOMI, 1998).

Although the variable CMJ was responsible for a major part of the P200 variance, the sprint$_{20m}$ increased significantly in 12% the explanation for the 200-m performance when inserted in association with the CMJ in the regression model.

The sprint$_{20m}$ is considered a neuromuscular index that, according to Numella et al. (2006), may represent characteristics of speed or, as well as CMJ, the athletes' level of muscle power (MARKOVIC et al., 2007). Thus, the contribution of the sprint$_{20m}$ in the P200 may be attributed to power of the concentric action of the knee extensor muscles, which determines the propulsive force generation during sprints (CHELLY; DENIS, 2001; SLEIVERT; TAINGAHUE, 2004). Reports in the literature have suggested that short-sprint training (< 5s) causes neural, metabolic ,and skeletal muscle adaptations, improving sprint running performance (ROSS et al., 2001; ROSS;

LEVERITT, 2001), thus, emphasizing the importance of this variable in the training control for 200-m races.

In the 400-m race, none of the neuromuscular variables investigated in this study showed a significant association with performance. Differently than what was found here, Miguel and Reis (2004) verified significant correlations (r = -0.68) of the CMJ with the 400-m performance in a heterogeneous group of 400-m sprinters (n=15). According to the authors, these associations could be diagnosed because the group was considered heterogeneous concerning running performance. This may explain the fact that the CMJ can not predict the P400 in our study, since, using the criteria by Gomes (1990), the group was considered homogeneous (VC = 3.59%).

The 400-m race is usually known as a "speed-endurance" event that demands the capacity of running close to high speed over a certain period of time - a mean of 52 seconds in the present study. Vittori (1991) identified fundamental functional requisites for success in this event such as: the combination of power, speed and endurance plus an appropriate effort distribution. In this sense, a hypothesis is that neuromuscular variables as CMJ could predict the P400 associated with other factors related with this race i.e., anaerobic capacity and aerobic power (NEVILL et al., 2008).

This ability to endure high power production over a certain period of time is a determinant factor for the 400 m, as demonstrated in the study previously mentioned (McGUIGAN et al., 2006). In the present study, this ability was estimated by the performance in the CJ_{15s}, which showed no significance influence to explain the races under study. However, this relationship would likely have occurred with the P200, in which mean time was 23 seconds, close to the maximal effort time performed in the CJ_{15s}.

Conclusion

In summary, we concluded that the CMJ is the main predictor of the 200-m performance. We observed that the $sprint_{20m}$, when inserted with the CMJ in the regression model, also contributes to predict the performance in this race, although its contribution is small. Thus, these indices are important for predicting the P200 as well as can be used in the evaluation and control of training of sprinters. On the other hand, in the 400m, none of the neuromuscular variables were associated with performance suggesting that other factors, probably associated with lactic anaerobic capacity, may be more significant in relation to this specific performance.

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