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Is Tensiomyography-Derived Velocity of Contraction a Sensitive Marker to Detect Acute Performance Changes in Elite Team-Sport Athletes?

Lucas A. Pereira, Rodrigo Ramirez-Campillo, Saul Martín-Rodríguez, Ronaldo Kobal, César C.C. Abad, Ademir F.S. Arruda, Aristide Guerriero, and Irineu Loturco

Purpose: To examine the variations in the velocity of contraction (V_c) assessed using tensiomyography, vertical jumping ability, and sprinting speed induced by 4 different exercise protocols (ie, strength, sprint, plyometric, and technical training sessions) in 14 male national-team rugby players (age 21.8 [2.6] y, weight 83.6 [8.5] kg, and height 177.4 [6.7] cm). ***Methods:*** Physical tests were conducted immediately before and after 4 distinct workouts in the following order: tensiomyography in the rectus femoris and biceps femoris muscles, squat and countermovement jumps, and 30-m sprint velocity. To analyze the differences in the assessed variables before and after each training session, the differences based on magnitudes were calculated. ***Results:*** After strength and plyometric workouts, the players presented possible to almost certain impairments in sprint and jump performance and in the V_c of the rectus femoris (effect sizes 0.26–0.64). After the sprint-training session, possible to very likely decreases were observed in the squat jump, 30-m sprint, and V_c of the biceps femoris (effect sizes 0.21–0.44). By contrast, after the technical training, athletes demonstrated a possible increase in the squat jump and V_c in both muscles examined (effect sizes 0.13–0.20). ***Conclusions:*** The main finding of this research is that, for the vast majority of results, the direction of changes observed in V_c were the same as those observed in performance assessments. This suggests that V_c might be used as a sensitive marker of acute variations in speed and power performance of elite team-sport athletes.

Keywords: sports, fatigue, muscle contractile capacity, muscle power

Fatigue can be defined as the incapacity to generate force or the increase in perceived effort when producing a submaximal force.[1,2] Due to its direct impacts on sport performance, this phenomenon has been extensively investigated in recent decades. Among the different studies related to fatigue, the acute responses of elite athletes to specific workouts (ie, technical, tactical, or physical training sessions) seem to be one of the most frequently examined topics. For example, Weakley et al[3] reported distinct vertical jump, perceptual, metabolic, and hormonal responses to traditional, superset, and triset resistance training sessions in university rugby union players. Thus, a more complete understanding of the actual acute responses to different exercise types is clearly warranted in team-sport disciplines.

One of the most common and practical ways to quantify the symptoms of fatigue associated with a given training session is by analyzing the prechange and postchange in vertical jump performance.[4–7] Indeed, a previous study has demonstrated that reductions in vertical jump height are accompanied by a significant increase in muscle soreness in response to a speed training stimulus in professional rugby players. Similarly, vertical jumping ability was significantly impaired at 72-hour postexercise (ie, a fatiguing Yo-Yo running protocol) in team-sport athletes.[5] Moreover, Cadore et al[4] demonstrated that different plyometric training volumes (ie, 100, 200, or 300 hurdle jumps) produced similar decrements in the vertical jumping ability of national-level rugby players. Although decreases in jump performance may be used to detect impairments in physical and physiological qualities, to date, it is not clear why this occurs. A possible explanation for these decrements could be related to changes in some muscle mechanical properties, such as muscle stiffness and time-related parameters (eg, contraction time). In fact, the close relationships between muscle mechanical properties and force–power production are well established in the literature.[8–10] Therefore, it is necessary to assess these critical muscle qualities after training interventions involving elite athletes.

Tensiomyography (TMG) is a novel noninvasive method that measures radial deformation of skeletal muscle, and in turn its contractile properties, in response to an external electrical stimulus.[11–14] Some TMG mechanical variables (eg, radial displacement [D_m], contraction time [T_c], and delay time [T_d]) have been shown to be sensitive to detect muscle fatigue[15,16] and able to discriminate athletes with distinct physical qualities[11] and training backgrounds. Recently, a novel TMG-derived measurement named "velocity of contraction" (V_c) (ie, $V_c = D_m/(T_c + T_d)$) has been proposed to identify acute and chronic changes in neuromuscular performance in nonathletic populations and elite athletes,[12,17] showing different and controversial results.[17–19] For example, it seems that V_c is able to detect acute impairments in maximum isometric force (in "strength-trained subjects," after distinct strength training protocols)[17] but not in vertical jump performance (in "healthy active subjects"[18] and junior tennis players,[19] after a plyometric exercise bout and 7 high-intensity interval training sessions, respectively).[18,19] Nevertheless, to the authors' knowledge, no study has attempted to simultaneously measure and quantify the acute responses in muscle mechanical

Pereira, Kobal, Abad, and Loturco are with NAR—Nucleus of High Performance in Sport, São Paulo, Brazil. Ramirez-Campillo is with the Laboratory of Human Performance, Quality of Life and Wellness Research Group, Dept of Physical Activity Sciences, University of Los Lagos, Osorno, Chile. Martín-Rodríguez is with Canarian Physical Education Licenciates College, Las Palmas de Gran Canaria, Gran Canaria, Spain. Arruda and Guerriero are with the Brazilian Rugby Confederation, São Paulo, Brazil. Guerriero is with the University of Rome Foro Italico, Rome, Italy. Loturco (irineu.loturco@terra.com.br) is corresponding author.

properties and physical performance of professional team-sport athletes who performed a variety of training protocols, within their actual training routine. Therefore, the aim of this study was to assess the sensitivity of V_c to detect meaningful changes in vertical jump and sprint performances induced by 4 different exercise protocols (ie, strength, plyometric, sprint, and technical training sessions) in national team rugby players.

Methods

Study Design

To assess the sensitivity of TMG parameters to detect changes in jump and sprint abilities induced by 4 distinct training sessions, rugby players arrived at the sports laboratory in a fasted state for at least 2 hours and having avoided caffeine and alcohol consumption in the 24 hours before the experimental procedures. The 4 training sessions were separated by at least 48 hours and performed in a randomized order. A schematic presentation of the study design is shown in Figure 1. The training sessions were part of the regular training routines of the players and consisted of strength, plyometric, sprint, and technical workouts. A detailed description of the training content in each session is presented in Table 1. Physical tests were conducted before and immediately after the 4 distinct training sessions in the following order: TMG in the rectus femoris (RF) and biceps femoris (BF) muscles, squat and countermovement jumps (SJ and CMJ), and 30-m sprint velocity (VEL). Prior to the vertical jump and sprint tests, athletes performed standardized warm-up protocols including general (ie, running at a moderate pace for 10 min followed by active lower-limb stretching for 3 min) and specific workouts (ie, submaximal attempts at each tested exercise). Between each test, a 15-minute interval was allowed to explain the following procedures and adjust the equipment. All athletes were well acquainted with testing procedures due to their constant assessments in our facilities.

Subjects

Fourteen male professional rugby players (age 21.8 [2.6] y, weight 83.6 [8.5] kg, height 177.4 [6.7] cm) participated in this study. Players were all members of the Brazilian national team training under the same regimens. Athletes were in the midterm of the competitive period and were tested during their regular training practices. The study was approved by the Anhanguera-Bandeirante ethics committee, and all subjects were informed of the inherent risks and benefits associated with study participation before signing informed consent forms.

TMG Assessment

The D_m, T_c, and T_d were recorded from both the RF and BF muscles from the dominant leg[20] using a TMG device (TMG

Table 1 Training Description of the 4 Different Sessions

Training session	Exercises	Volume (sets × repetitions)	Intensity
Strength training	Deadlift hex bar	3×4	80–85% 1RM
	Push press	3×4	70–80% 1RM
	Squat	3×4	80–85% 1RM
	Jump squat	3×4	50% BM
Plyometric training	Horizontal triple jump	4×3	Maximum
	Drop jumps (45 cm)	4×6	
	Drop jumps (60 cm)	4×6	
	Hurdle jumps (76 cm)	4×6	
Sprint training	10 m	1×4	Maximum
	40 m	1×4	
	L drill	1×4	
	Zigzag	1×4	
Technical training	Ball carrying with change of direction		
	Pass drills		
	Positioning and tackle		
	Pass drills with numerical superiority (3×1, 3×2)		

Abbreviations: 1RM, 1-repetition maximum; BM, body mass.

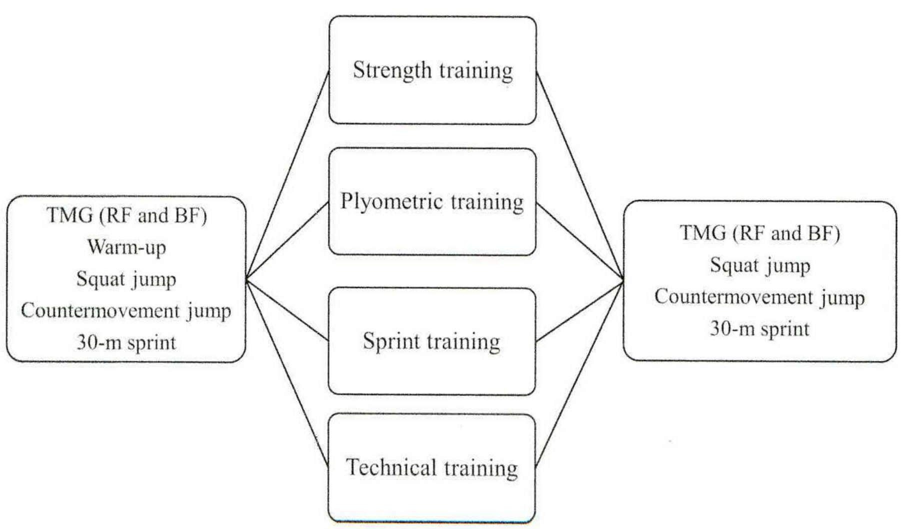

Figure 1 — Schematic presentation of the study design. The order of the training sessions was randomized. BF indicates biceps femoris; RF, rectus femoris; TMG, tensiomyography.

Measurement System; TMG-BMC Ltd, Ljubljana, Slovenia). The D_m corresponds to the radial movement of the muscle belly expressed in millimeters and is related to muscle belly stiffness. The T_c is obtained by determining the time lapse from 10% to 90% of D_m. T_d represents the time spent to reach 10% of the total movement after stimulation.[16] TMG-derived V_c was calculated by dividing D_m by the sum of T_c and T_d. The RF measurements were performed with the athletes in a supine position using a triangular wedge foam cushion to maintain the legs in a position corresponding to 120° of knee flexion. The sensor was placed 50% along the line from the anterosuperior iliac spine to the superior part of the patella. For BF measurements, the athletes adopted a prone position, with their knees at 180% of full extension. The sensor was placed 50% along the line between the ischial tuberosity and the lateral epicondyle of tibia. An accurate pressure transducer (Trans-TekwGK40, Ljubljana, Slovenia) was positioned perpendicular to the muscle axis. Recording of the D_m took place in the muscle belly after an external electrical stimulus. To induce the twitch responses, adhesive 5 × 5-cm electrodes (Compex Medical SA, Ecublens, Switzerland) were connected to an electric stimulator and positioned on the muscle surface, following the arrangement of the fibers.[12,17] The distance between the measurement point and the electrodes was standardized between 55 and 60 mm. The electric pulse was set to 1 ms and the signal amplitude started at 30 mA. For each pulse, current amplitude was increased by 10 mA, until the maximal displacement of the muscle belly was reached. To avoid fatigue or potentiation effects, a 15-second resting period was allowed between electrical stimuli.[21] The same experienced examiner conducted all measurements.

Vertical Jumps

Vertical jump height was assessed using SJ and CMJ. In the SJ, athletes were required to remain in a static position with a 90° knee flexion angle for ~2 seconds before jumping, without any preparatory movement. In the CMJ, athletes were instructed to execute a downward movement followed by complete extension of the legs and were free to determine the countermovement amplitude to avoid changes in jumping coordination. All jumps were executed with the hands on the hips, and the athletes were instructed to jump as high as possible. The jumps were performed on a contact platform (Elite Jump®; S2 Sports, São Paulo, Brazil). A total of 5 attempts were allowed for each jump, interspersed by 15-second intervals. The best attempts for the SJ and CMJ were used for the analyses.

Sprinting-Speed Test

For the sprint test, 3 pairs of photocells (Smart-Speed; Fusion Equipment, Brisbane, Australia) were positioned at distances of 0, 10, and 30 m along the sprinting course. VEL was calculated as the distance traveled over a measured time interval. Athletes sprinted twice, from a standing position, 0.3 m behind the starting line. A 3-minute rest interval was allowed between the 2 attempts, and the fastest time was considered for the analyses.

Statistical Analysis

Data are presented as mean (SD). Due to the large interindividual variability in the dependent variables of this study, data were log transformed for the analysis and then back transformed to facilitate their presentation and interpretation in the "Results" section. To analyze the differences in the vertical jumps, VEL, and V_c in the RF and BF muscles, before and after each training session, the differences based on magnitudes were calculated.[22] The magnitude of the changes in the different performance variables were expressed as standardized mean differences (Cohen *d*, effect size [ES]). The smallest worthwhile change was set using the Cohen principles for a small ES (0.2) for each variable tested.[23] The quantitative chances of finding differences in the variables tested were assessed qualitatively as follows: <1%, almost certainly not; 1% to 5%, very unlikely; 5% to 25%, unlikely; 25% to 75%, possible; 75% to 95%, likely; 95% to 99%, very likely; and >99%, almost certain. A meaningful difference was considered using the mechanistic inference, based on threshold chances of 5% for substantial magnitudes.[24] Therefore, if the chances of having better and poorer results were both >5%, the true difference was assessed as unclear. In addition, ESs were qualitatively interpreted using the following thresholds: <0.2, trivial; 0.2 to 0.6, small; 0.6 to 1.2, moderate; 1.2 to 2.0, large; 2.0 to 4.0, very large; and >4.0 near perfect.[24] The Pearson product–moment correlation coefficient was used to analyze the relationships between the changes in V_c values, vertical jump heights, and VEL after the training protocols. The threshold used to qualitatively assess the correlations was based on the following criteria: <0.1, trivial; 0.1 to 0.3, small; 0.3 to 0.5, moderate; 0.5 to 0.7, large; 0.7 to 0.9, very large; and >0.9 nearly perfect.[24] The significance level was set as $P < .05$. The reliability of the V_c, vertical jumps, and VEL results was calculated using the 4 pretraining measures through the intraclass correlation coefficient (ICC; analyzing the average measures) and coefficient of variation. The correlational analysis and ICC calculations were performed using the SPSS software package (version 22.0; SPSS, Inc, Chicago, IL). The ICC and coefficient of variation for the SJ, CMJ, and VEL 10 and 30 m were all >.90 and <5%, respectively. The ICC and coefficient of variation for V_c RF were .92 and 10% and for V_c BF were .55 and 13%, respectively.

Results

Figure 2 depicts the percentage changes in the vertical jumps, VEL, and V_c in RF and BF muscles in the strength-training session.

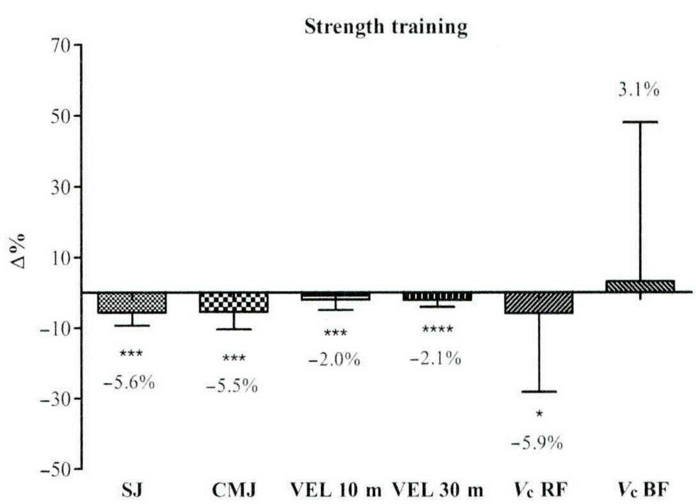

Figure 2 — Percentage change (Δ%) in the SJ, CMJ, VEL, and V_c in RF and BF muscles in the strength-training session. BF indicates biceps femoris; CMJ, countermovement jumps; RF, rectus femoris; SJ, squat jump; V_c, velocity of contraction; VEL, sprinting velocity. *Possible, ***very likely, and ****almost certain changes.

Likely reductions in SJ (pre 39.7 [5.5] cm; post 37.4 [5.1] cm; ES 0.41), CMJ (pre 41.9 [4.9] cm; post 39.6 [5.7] cm; ES 0.42), and VEL 10 m (pre 5.74 [0.18] m·s^{-1}; post 5.62 [0.21] m·s^{-1}; ES 0.64) were observed, while an almost certain decrease was observed for VEL 30 m (pre 7.09 [0.25] m·s^{-1}; post 6.94 [0.28] m·s^{-1}; ES 0.56). In relation to the TMG variables, a possible impairment was observed in the V_c RF (pre 0.148 [0.062] mm·ms^{-1}; post 0.140 [0.069] mm·ms^{-1}; ES 0.14), whereas no meaningful difference was observed for the V_c BF (pre 0.049 [0.019] mm·ms^{-1}; post 0.044 [0.014] mm·ms^{-1}; ES 0.17).

Figure 3 demonstrates the percentage changes in the performance variables tested and the TMG-derived V_c in the plyometric-training session. A possible impairment in VEL 10 m (pre 5.68 [0.27] m·s^{-1}; post 5.60 [0.21] m·s^{-1}; ES 0.28), a likely decrease in the SJ (pre 38.9 [5.7] cm; post 36.9 [5.8] cm; ES 0.33), and a very likely reduction in the CMJ (pre 41.4 [6.3] cm; post 38.8 [6.2] cm; ES 0.40) and VEL 30 m (pre 7.04 [0.23] m·s^{-1}; post 6.93 [0.25] m·s^{-1}; ES 0.48) were observed. Meanwhile, a likely and a possible decrease in the V_c RF (pre 0.159 [0.058] mm·ms^{-1}; post 0.139 [0.063] mm·ms^{-1}; ES 0.43) and V_c BF (pre 0.047 [0.027] mm·ms^{-1}; post 0.040 [0.021] mm·ms^{-1}; ES 0.39), respectively, were also observed after the plyometric-training session.

Figure 4 depicts the percentage changes in the vertical jumps, VEL, and V_c in RF and BF muscles in the sprinting-training session. A possible reduction in the SJ (pre 39.6 [6.3] cm; post 38.1 [6.8] cm; ES 0.21) and a very likely decrease in VEL 30 m (pre 7.05 [0.26] m·s^{-1}; post 6.93 [0.28] m·s^{-1}; ES 0.44) were observed. No meaningful differences were observed in the CMJ (pre 41.3 [6.4] cm; post 41.0 [7.4] cm; ES 0.04) or VEL 10 m (pre 5.56 [0.24] m·s^{-1}; post 5.50 [0.23] m·s^{-1}; ES 0.22). In relation to the TMG variables, a likely impairment was observed in the V_c BF (pre 0.047 [0.022] mm·ms^{-1}; post 0.037 [0.017] mm·ms^{-1}; ES 0.43), whereas no meaningful difference was observed in the V_c RF (pre 0.160 [0.066] mm·ms^{-1}; post 0.146 [0.046] mm·ms^{-1}; ES 0.09).

Figure 5 demonstrates the percentage changes in the performance variables tested and the TMG-derived V_c in the technical-training session. A possible increase in the SJ (pre 38.6 [6.3] cm; post 40.0 [6.5] cm; ES 0.20) was observed. No meaningful changes were observed in the CMJ (pre 40.9 [7.4] cm; post 41.2 [7.4] cm; ES 0.03), VEL 10 m (pre 5.43 [0.27] m·s^{-1}; post 5.49 [0.28] m·s^{-1}; ES 0.19), or VEL 30 m (pre 6.90 [0.31] m·s^{-1}; post 6.92 [0.32] m·s^{-1}; ES 0.04). Meanwhile, possible increases were observed in the V_c RF (pre 0.128 [0.064] mm·ms^{-1}; post 0.139 [0.068] mm·ms^{-1}; ES 0.13) and V_c BF (pre 0.039 [0.024] mm·ms^{-1}; post 0.048 [0.029] mm·ms^{-1}; ES 0.27) after the technical-training session. Table 2 shows the correlation coefficients between the changes in V_c (in both muscles), vertical jump heights, and VEL after the 4 training protocols.

Discussion

This study aimed to assess the variations in V_c, vertical jumping ability, and sprinting speed induced by 4 different exercise protocols in national team rugby players. Overall, after the strength and

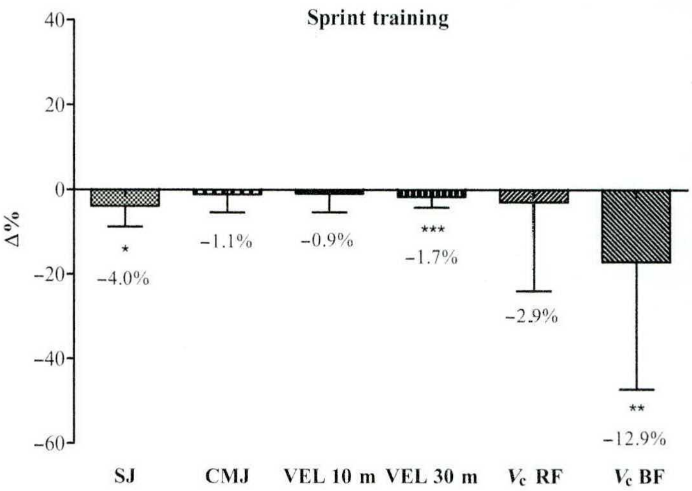

Figure 4 — Percentage change (Δ%) in the SJ, CMJ, VEL, and V_c in RF and BF muscles in the sprinting-training session. BF indicates biceps femoris; CMJ, countermovement jumps; RF, rectus femoris; SJ, squat jump; V_c, velocity of contraction; VEL, sprinting velocity. *Possible, **likely, and ***very likely changes.

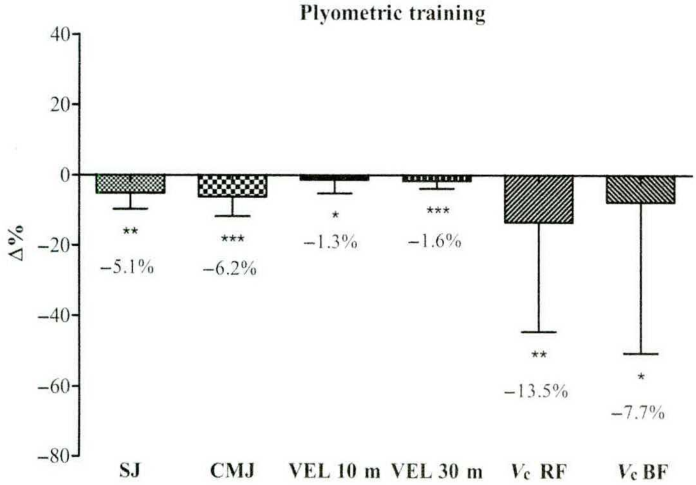

Figure 3 — Percentage change (Δ%) in the SJ, CMJ, VEL, and V_c in RF and BF muscles in the plyometric-training session. BF indicates biceps femoris; CMJ, countermovement jumps; RF, rectus femoris; SJ, squat jump; V_c, velocity of contraction; VEL, sprinting velocity. *Possible, **very likely, and ***almost certain changes.

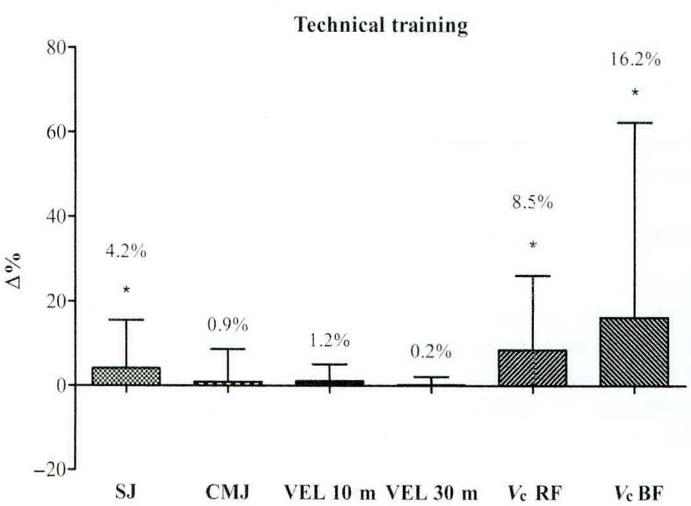

Figure 5 — Percentage change (Δ%) in the SJ, CMJ, VEL, and V_c in RF and BF muscles in the technical-training session. BF indicates biceps femoris; CMJ, countermovement jumps; RF, rectus femoris; SJ, squat jump; V_c, velocity of contraction; VEL, sprinting velocity. *Possible changes.

Table 2 Correlation Coefficients Between the Changes in Contraction Velocity (in Both Muscles), Vertical-Jump Height, and Sprint Velocity After the 4 Training Protocols

	Training protocols							
	Strength		Plyometric		Sprint		Technical	
	RF	BF	RF	BF	RF	BF	RF	BF
Squat jump	.76*	−.15	.39	.19	.04	.63*	.01	.19
Countermovement jump	−.20	−.17	.73*	.25	−.04	.09	−.15	.16
Sprint velocity 10 m	−.21	−.16	.33	.46	−.06	−.02	−.09	.08
Sprint velocity 30 m	−.24	−.01	.38	.69*	−.06	.08	−.37	−.17

Abbreviations: BF, biceps femoris; RF, rectus femoris.
*$P < .05$.

plyometric training sessions, the players presented meaningful impairments in all performance tests and in the V_c RF. In addition, after sprint training, we observed important decreases in SJ, VEL 30 m, and V_c BF. The same does not hold true for the technical-training session after which athletes demonstrated meaningful increases in SJ height and V_c in both muscles examined. The main finding of this research is that, in the vast majority of results, the direction of changes observed in the V_c and in performance assessments were exactly the same. This indicates that the V_c is a sensitive physiological marker of acute variations in speed and power performance of team-sport athletes. As far as we know, this is the first study to observe this direct connection in national team rugby players.

These results are partially in line with previous investigations that reported: (1) chronic changes in V_c and speed performance in elite soccer players after a competitive period[12] and (2) acute changes in V_c and "muscle force" immediately after different strength training protocols in moderately trained subjects.[17,19] Accordingly, Loturco et al[12] revealed that reductions in linear and change of direction speed were accompanied by meaningful impairments in the V_c in both RF and BF muscles, after an 8-week training period in professional soccer players. de Paula Simola et al[17] also showed reductions in maximal voluntary isometric contractions and V_c RF following strength training session based on "drop sets" or on a "flywheel resistance machine"; however, no changes were observed after "eccentric overload" and "multiple sets" strength training protocols, as well as "plyometrics" in male resistance trained subjects. Importantly, the same study[17] also demonstrated significant correlations between the changes in V_c and in maximal voluntary isometric contractions after different resistance training protocols. For the latter, it is plausible to suggest that the sample characteristics (ie, nonathletes) and lower training volume (compared with the present work, ie, only one exercise performed in each training protocol) might have influenced the divergent responses observed in V_c. Similarly, previous studies performed with healthy active subjects[18] and junior tennis players[19] revealed that the V_c RF was not as sensitive as the CMJ for detecting muscular fatigue after a "plyometric exercise bout"[18] and a "short-term high-intensity interval training program."[19] Again, the differences in the sample features, experimental designs, and training protocols may be accounted for by the distinct V_c responses observed by Valenzuela et al[18] and Wiewelhove et al.[19] Nonetheless, in general, our data corroborate and extend previous findings demonstrated that V_c is a practical and accurate marker of temporal changes in athletic performance.[12,17] It is worth noting that in this study, the changes in V_c in BF and RF were evaluated immediately after 4 different training protocols (ie, strength, power, speed, or technical training sessions), which may have important implications for practice and future research.

In this regard, with the exception of V_c BF in the strength-training session and V_c RF in the sprint-training session, all the other V_c measures presented meaningful decreases after the strength, sprint, and plyometric workouts. As reported in Table 1, all training sessions were performed during the competitive period, under real situations and at maximum effort levels. Therefore, the substantial reductions in TMG-derived V_c and speed and power performance observed herein suggest that the national team rugby players experienced an "at least transient" effect of muscle fatigue after the different training protocols. As impairments in neuromuscular ability were observed in both voluntary (eg, sprints and jumps) and involuntary actions (eg, TMG), it is plausible to speculate that these fatigue-related changes are more associated with peripheral factors.[1,25] Although it is not possible to determine the actual causes of these acute responses, they might be triggered by a sequence of neuromechanical events, such as reductions in motoneuron excitability, impaired excitatory drive to α-motoneurons, reduced sarcoplasmic reticulum Ca^{2+} release rate, and excitation–contraction coupling impairment.[1,26–28] Further studies are clearly warranted to better elucidate and explore these neuromechanical interactions.

Interestingly, the V_c in both RF and BF muscles presented meaningful increases after the technical workout. These enhancements probably affected the SJ performance, allowing athletes to jump higher from a squat position, which relies more on rapid force production from 0 velocity, namely on muscle contractile capacity.[29] By contrast, these improvements were not capable of inducing meaningful increases in motor tasks, which are strongly dependent on the stretch-shortening cycle (ie, CMJ and sprints).[25,30] It is important to emphasize that the technical workouts are specifically designed to improve sport-specific skills (ie, technical and tactical abilities); therefore, these sections should be performed in the absence of fatigue. It is well established that fatigue usually reduces technical accuracy,[31,32] affecting coordinative aspects of (more precise) movements, which can be a serious concern when dealing with top-level athletes, mainly during critical periods of training and competition (eg, close to matches). As such, we can assume that the technical workout was properly structured and organized by the national team technical staff, allowing rugby players to effectively develop their sport-specific abilities during this training protocol.[33]

This study examined the prechange and postchange of a single session of 4 different training types, thereby avoiding analyzing the reliability of the responses observed at each time point. Unquestionably, this is an inherent limitation. Nevertheless, as we are dealing with well-acquainted professional athletes with these respective training and testing routines, our data may help practitioners to better monitor the actual effects of distinct training sessions through the use of practical and noninvasive TMG measurements.[12,13,16] Furthermore, it must be highlighted that only a few significant correlations were detected between the respective responses in V_c, sprinting, and jumping abilities (Table 2). Thus, although variations in V_c may be interpreted as indicative of variations in performance, they seem not to reflect (to the same extent) the magnitude of the changes in speed- and power-related capacities. Future studies should be conducted to investigate whether these muscle mechanical responses could also be used to monitor the changes in athletic performance over longer periods of time (eg, post 24 or 48 h) or after interventional studies executed with team-sport athletes.

Practical Applications

The impairments in speed and power performance, which occur immediately after strength, sprint, and plyometric training sessions in elite rugby players are accompanied by meaningful reductions in the V_c, in both RF and BF muscles. Based on these findings, coaches and sport scientists who usually work with TMG measurements are strongly encouraged to adjust and adequate the training strategies of their athletes in accordance with the acute responses in physical performance, which can be easily assessed by the worthwhile variations in the TMG-derived V_c. Due to its simple, passive, and noninvasive characteristics, this evaluation can be performed on a daily basis, even after very intensive workouts, which might be a great advantage in high-performance sports.

Conclusions

The TMG-derived V_c in both RF and BF muscles could be used to evaluate the changes in speed and power performance which occur immediately after specific training sessions in elite rugby players.

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