

# Countermovement jump variables not tensiomyography can distinguish between sprint and endurance focused track cyclists

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**ABSTRACT:** This study investigated the reliability and discriminative ability of tensiomyography and countermovement jump variables as measures of a muscles contractile properties in a cohort of elite endurance and sprint track cyclists. Tensiomyography was performed on the vastus lateralis (VL) and rectus femoris (RF) muscles in sprint track cyclists (N = 8) and endurance track cyclists (N = 8). Additionally, the participants completed a countermovement jump on a force plate. Tensiomyography measurements obtained from the RF displayed greater reliability (ICC = 0.879–0.997) than VL (ICC = 0.746–0.970). Radial muscle belly displacement (Dm), contraction time (Tc) and delay time (Td) demonstrated the most reliable TMG measurements. Only two variables displayed acceptable coefficient of variation (RF Td = 8.89, VL Td = 6.88), other variables presented as unacceptable. The TMG variables were unable to discriminate between endurance and sprint track cyclists whilst the CMJ variables could. Due to the high variability in measurements and its inability to distinguish between sprint and endurance based track cyclists TMG should be used cautiously in this athlete population and if available the CMJ is a more appropriate assessment of leg muscle function.

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## INTRODUCTION

Recently, tensiomyography (TMG) has received attention as a non-invasive assessment of the contractile properties of isolated superficial muscles [1, 2, 3]. Tensiomyography has gained traction by sport and exercise scientists, health specialists and coaches as a portable, time-efficient measuring tool of muscle response and mechanical muscle analysis through sub-maximal electrical stimulation and digital displacement assessment [4]. Tensiomyography measures spatial and temporal parameters of radial displacement of the muscle belly in response to an electrical stimulus [5]. Assessment using TMG functions under the assumption that the amount of displacement observed in the muscle is associated with the force developing capabilities of the muscle [6].

Tensiomyography has been incorporated into athlete testing, monitoring and rehabilitation programs as it offers additional insight into muscle contractile properties. However, TMG's ability to identify muscular characteristics that influence performance needs further investigation. The construct validity and reliability of TMG have been established over recent years, however, it has not been thoroughly investigated in an elite athlete population. Recent research has investigated the specific neuromuscular characteristics of road cyclists utilising TMG in the lower extremities [7]. The results identified that a greater radial muscle belly displacement

of the vastus lateralis (VL) and a longer rectus femoris (RF) contraction time may predict a higher peak power output during a maximal incremental test on a cycle ergometer. Thus, it provides impetus to investigate similar muscle contraction characteristics in elite track cyclists and identify the potential differences between different track cycling demographics. Additionally, a common and practical method of assessing lower-body muscle function for the purposes of athlete monitoring and talent identification is a countermovement jump (CMJ). Variables obtained from a CMJ have been shown to discriminate between levels of performers and athletes with differing physiological demands [8, 9]. A comparison of variables obtained from TMG to the commonly used CMJ can provide practitioners with valuable insight into the diagnostic utility of TMG.

Published literature has indicated that the VL provides maximum activation through the propulsion phase of the pedal cycle [7, 10]. Furthermore, research suggests that through electromyography RF activation was significantly greater than compared to other quadriceps muscles during the 1st and 4th quadrant of the pedalling cycle [1]. These findings reinforce the importance of both muscles during cycling and provide rationale to measure the contractile properties of these muscles through TMG.

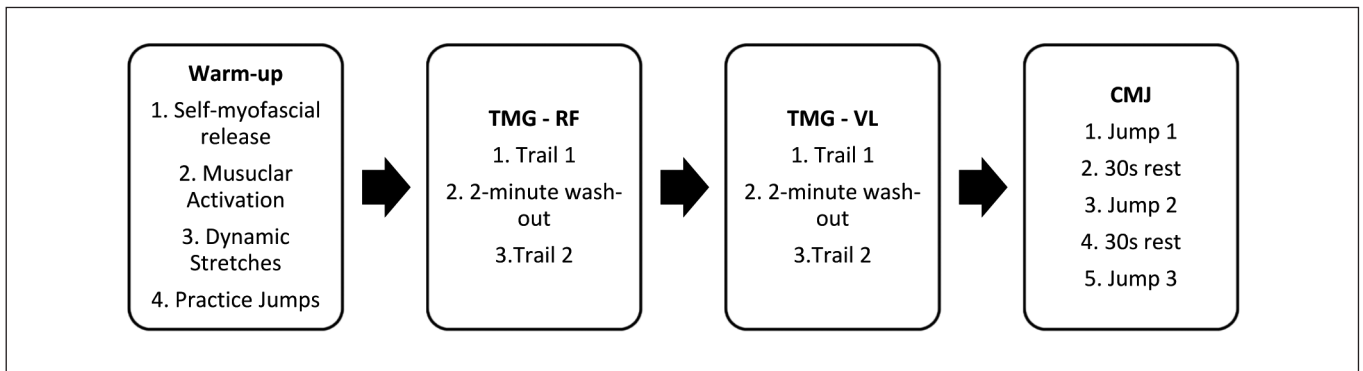


FIG. 1. Flow chart of study design.

Assessing the contractile properties of these muscles in track cyclists through TMG may be of interest to sports scientists and performance coaches working with this population of athletes. It has been well established that sprint cyclists obtain certain muscle performance characteristics, due to the power demands of their sport, when compared to their endurance counterparts [11]. When comparing the differences in sprint and endurance track cycling, the sprint cyclists cover less distance but generate a significantly greater amount of speed. Sprint track cycling involves short, explosive efforts throughout 3–8 laps and can generate speeds of around 77 km/h. Whereas, endurance track cycling requires longer sustained efforts of distances between 12–16 laps for the individual and team pursuit races and generates speed around 58 km/h. Performance in both sprint and endurance track cycling is influenced by the athlete's lower-body power capacity. Therefore the purpose of this investigation was to (i) determine the reliability of TMG measurements of the RF and VL and (ii) Determine if both TMG and CMJ variables can distinguish between sprint and endurance track cyclists and (iii) compare how the contractile properties of these muscle relate to variables obtained from a common test of lower-body force production, the CMJ, in elite track cyclists with an either an endurance and sprint background.

## MATERIALS AND METHODS

### *Experimental approach to the problem*

This observational study involved the use of data collected from the athlete's routine testing program. Tensiomyography and CMJ results were gathered across 1 day. Participants were divided into sprint track cycling or endurance track cycling based upon the cycling discipline they compete in. The TMG testing method was performed on the VL and RF muscles, due to their importance during cycling. Only TMG parameters that demonstrated the greatest reliability were used for additional analysis.

### *Participants*

Convenience sampling was employed utilizing the athletes involved in the track cycling program from a state institute of sport. Eight elite

sprint track cyclists (Male = 4, Female = 4) and eight elite endurance track cyclists (Male = 5, Female = 3) participated in the study (age  $17.4 \pm 1.2$  years; height  $176.1 \pm 9.1$  cm; body mass  $70.30 \pm 5.6$  kg). All athletes were injury free at the time of testing and written consent was provided by the participating organisation for the use of their data, collected as part of a player's contractual arrangements. Ethical approval was obtained from the Federation University Australia Human Research Ethics Committee application number C19–010.

### *Procedures*

Prior to the collection of data, athletes completed a 15-minute warm-up consisting of self-myofascial release, neuromuscular activation exercises and lower-body dynamic stretches. At the conclusion of the warm-up, the athletes completed practice jumps. The athletes were informed that the aim of the warm-up was to prepare for maximal effort in a CMJ test. Following completion of the warm-up the TMG analysis was performed prior to the execution of the three CMJs.

Tensiomyography testing of the RF and VL muscles of the right leg was performed using a TMG-S1 stimulator (EMF-Furlan & Co. Ljubljana, Slovenia). Radial muscle belly displacement was measured by a displacement transducer contained within a spring-loaded probe (GK40, Panoptik Ljubljana, Slovenia). Athletes were instructed to lay supine in a relaxed position on a bench with arms by their side. The athlete's right leg was elevated on a triangular foam cushion to place the knee joint in a fixed  $120^\circ$  angle. The displacement transducer, attached to a spring-loaded probe, was positioned perpendicular to the thickest part of the muscle belly of each individual muscle at a constant spring pressure of approximately  $1.5 \times 10^{-2}$  N/mm<sup>2</sup> over an area of 113 m<sup>2</sup> [6]. Due to the natural individual anatomical differences of each athlete, the position of the sensor was identified by asking the athlete to extend their knee against resistance provided by the investigator. After the location for transducer placement was identified, two square self-adhesive stimulating electrodes (Med-Fit, Stockport, UK) were placed along the muscle belly approximately 2.5 cm dorsal and proximal to the sensor. This inter-electrode distance has

been identified through literature to provide the most accurate measurements for the RF and VL muscles [5]. The testing began by delivering a 1ms wide pulse of 20 mA, followed by an increase of 10 mA increments until radial muscle belly displacement plateaued or until no further increase over 2 stimulations was identified through the twitch response curve. This level was recorded as the maximal level of contraction and the variables associated with this stimulation were used for analysis. Each increment in stimulation amplitude was separated by a 10 s interval to minimize the influence of fatigue and potentiation. A 2-minute washout was allocated prior to conducting the second set of measurements on the RF, before moving the electrodes and probe onto the VL muscle.

Lower-body muscular force production measures were obtained through a CMJ conducted on a bilateral force plate with a sampling frequency of 1000Hz (ForceDecks, Vald Performance, Queensland Australia). The CMJ assessment started with the athlete standing on the force plate to calculate body mass. A wooden dowel was placed across the athletes' shoulders to eliminate arm swing during the jump and isolate force production from lower-body. Athletes were instructed to perform a countermovement to a self-selected depth then "jump as high as possible" [12]. The athletes performed three CMJ's with 30 seconds between each jump. A multitude of variables were incorporated for the analysis, as previous literature suggests the most reliable variables may not be the most efficacious in monitoring and assessment of muscular performance characteristics in athletes [13]. The best measurement for each variable regardless of the jump was retained for analysis.

*Statistical Analysis*

Statistical analysis was undertaken using the Statistical Package for the Social Sciences (SPSS, version. 25.0, IBM Corporations, Somers,

New York, USA). Prior to the statistical analysis, a Shapiro-Wilk test was conducted to determine the normality of the data to ensure the appropriateness of utilizing parametric statistics. To determine the reliability of TMG variables, the Intra-Class Correlation Coefficient (ICC), the Coefficient of Variation (CV) and the Typical Error (TE) were calculated. Additionally, a paired samples t-test was completed to determine bias between trail 1 and trail 2. As only the variables that were determined to be reliable were used to distinguish between the two track cycling disciplines and determine the relationships between variables from TMG and the CMJ, a coefficient of variation (CV) percentage below 5% was considered optimal, 5–10% acceptable and above 10% unacceptable [14]. A One-Way Analysis of variance (ANOVA) was conducted to determine if significant differences existed between the sprint track cyclists and endurance track cyclists. The magnitude of the difference between groups was assessed using Hopkins effect sizes [15]. Effect sizes were categorised as follows; 0.00–0.19 = Trivial; 0.2–0.59 = Small; 0.60–1.19 = Moderate; 1.20–1.99 = Large, 2.00–3.99 = Very large, > 4.00 = Nearly perfect. Pearson correlations were conducted between all CMJ and the TMG variables that were identified as being reliable. Correlation coefficients were classified as 0–0.09 = Trivial; 0.1–0.29 = Small; 0.3–0.49 = Moderate; 0.5–0.69 = Large and 0.7–0.89 = Very large [15].

**RESULTS**

*Reliability of TMG Variables*

As indicated by the ICC's and CV's presented in Table 1. there was substantial variability in results across multiple variables. However, measurements obtained from the RF demonstrated greater reliability (ICC = 0.879–0.997) than those obtained from the VL (ICC = 0.746–0.970). Based upon the CV's, ICC's and TE's, the

**TABLE 1.** Reliability of TMG variables.

	<b>T1</b>	<b>T2</b>	<b>% Difference</b>	<b>P-Value</b>	<b>ICC</b>	<b>TE</b>	<b>CV%</b>
	<b>Mean (SD)</b>	<b>Mean (SD)</b>					
RF Tc (ms)	33.8 (3.9)	34.5 (4.4)	2.09	.027*	.951	.289	12.13
RF Ts (ms)	99.4 (44.7)	98.5 (43.1)	-0.87	.346	.997	.892	43.70
RF Tr (ms)	55.0 (40.4)	58.3 (39.6)	5.90	.527	.879	5.01	69.55
RF Dm (mm)	8.4 (1.8)	8.3 (1.8)	-1.38	.205	.980	.088	21.36
RF Td (ms)	27.4 (2.4)	27.6 (2.5)	0.57	.192	.982	.114	8.89
VL Tc (ms)	24.1 (2.8)	24.8 (3.6)	3.30	.039*	.884	.352	13.09
VL Ts (ms)	78.7 (43.3)	82.5 (43.3)	4.76	.628	.765	7.572	52.95
VL Tr (ms)	42.3 (33.3)	48.5 (34.5)	14.73	.318	.746	6.041	73.87
VL Dm (mm)	6.1 (2.1)	6.0 (1.8)	-0.69	.742	.970	.125	32.23
VL Td (ms)	23.6 (1.5)	23.9 (1.8)	1.36	.073	.907	.166	6.88

T1- Trial 1; T2- Trial 2 RF- Rectus Femoris; VL – Vastus Lateralis; Tc – Contraction time; Ts – Sustain time; Tr – Time to relaxation; Dm – Muscle belly displacement; Td – Delay time. \* = Statistically significant difference.

only TMG variable that displayed acceptable reliability were Delay Time (Td), Muscle Displacement (Dm), Contraction Time (Tc). The reliability of TMG variables from both the VL and RF are presented in Table 1.

#### *Differences in TMG Variables between Endurance and Sprint Cyclists*

As reported in Table 2. No TMG variables were significantly different between the sprint and endurance track cyclists. However, Dm of the RF displaying a non-significant moderate effect towards sprint cyclists in the difference between endurance and sprint cyclists.

#### *Differences in countermovement jump variables between endurance and sprint cyclists*

Table 2. displays the differences in CMJ variables for sprint and endurance track cyclists. All lower body force variables obtained from the CMJ were lower in the endurance cyclists compared to the sprint

cyclists; jump height determined by the impulse-momentum equation (-25.97%) and peak power (-25.42%) showing the greatest disparity. Concentric mean power/BM, concentric peak velocity, jump-height determined via flight time, jump height determined via the impulse-momentum, peak power and peak power/BM were all significantly greater ( $P < 0.05$ ) in the sprint compared to the endurance cyclists.

#### *Relationship between TMG and CMJ Variables*

For the correlations between TMG and CMJ jump performance, a mean score between both trails was used for the TMG variables. Additionally, only contraction time (Tc), radial muscle displacement (Dm) and delay time (Td) results were used as these were the variables that demonstrated the greatest reliability. Table 3 displays the Pearson correlation (r) between each CMJ variable and the TMG variables. No TMG variables were significantly related with the CMJ variables for both sprint and endurance track cyclists.

**TABLE 2.** CMJ and TMG mean results between sprint and endurance cyclists.

Variable	Sprint	Endurance	% Difference from Sprint	P-Value	ES
<b>CMJ Variables</b>					
Con Mean Force (N)	1361.37 ± 267.34	1182.37 ± 149.83	-14.07	0.12	0.82
Con Mean Power (W)	2039.25 ± 422.20	1667.75 ± 323.50	-20.04	0.06	0.98
Con Mean Power/BM (W/kg)	29.98 ± 4.78	24.15 ± 3.76	-21.54	0.01*	1.35
Con Peak Force (W/kg)	1726.25 ± 401.79	1518.87 ± 216.15	-12.78	0.21	0.64
Con Peak Velocity (ms)	3.00 ± 0.23	2.67 ± 0.22	-11.64	0.01*	1.46
Contraction Time (ms)	981.12 ± 127.65	1061.12 ± 142.22	7.83	0.25	0.59
Flight Time (ms)	573.37 ± 50.25	503.25 ± 58.73	-13.02	0.02*	1.28
Jump Height (cm)	42.85 ± 7.54	33.00 ± 6.21	-25.97	0.01*	1.42
Mov Start to Peak Force (s)	0.81 ± 0.24	0.89 ± 0.21	9.41	0.46	0.35
Mov Start to Peak Power (s)	0.93 ± 0.13	0.99 ± 0.13	6.25	0.37	0.47
Peak Net Take off Force/BM (N/kg)	14.18 ± 2.41	12.21 ± 2.45	-14.92	0.12	0.81
Peak Power (W)	4110.25 ± 1024.77	3183.75 ± 571.34	-25.42	0.04*	1.11
Peak Power/BM (W/kg)	56.83 ± 6.06	46.21 ± 7.20	-20.61	0.00*	1.59
<b>TMG Variables</b>					
RF Tc (ms)	35.18 ± 4.45	33.14 ± 3.85	-5.97	0.34	0.49
RF Dm (mm)	9.16 ± 2.08	7.60 ± 1.14	-18.61	0.08	0.93
RF Td (ms)	27.66 ± 3.15	27.39 ± 1.77	-0.98	0.83	0.10
VL Tc (ms)	24.93 ± 3.68	24.06 ± 2.70	-3.55	0.59	0.26
VL Dm (mm)	5.61 ± 1.80	6.56 ± 2.16	15.61	0.36	0.47
VL Td (ms)	23.47 ± 2.00	24.13 ± 1.17	2.77	0.43	0.40

Note: Con- Concentric; RF – Rectus femoris; VL – Vastus Lateralis; Tc- Contraction time; Dm; Muscle displacement; Td – Delay time.  
\* = statically significant difference.

**TABLE 3.** Pearson correlation values between mean TMG variables and CMJ results.

	RF Tc (M)	RF Dm (M)	RF Td (M)	VL Tc (M)	VL Dm (M)	VL Td (M)
Con Mean Force (N)	.213	.033	.010	.134	.046	.021
Con Mean Power (W)	.091	-.009	-.085	-.055	.064	.044
Con Mean Power/BM (W/kg)	.181	.210	-.063	-.009	-.001	-.096
Con Peak Force (N)	.244	-.024	-.057	.090	-.062	.036
Con Peak Velocity (m/s)	.214	.249	.086	.019	.074	-.041
Contraction Time (ms)	-.160	-.420	.079	-.106	-.265	-.146
Jump Height (cm)	.190	.254	.073	.032	.033	-.060
Start to Peak Force (s)	-.246	-.384	.060	-.302	-.259	-.314
Start to Peak Power (s)	-.147	-.352	.079	-.123	-.254	-.139
Peak Power (W)	.180	.097	.014	.076	-.005	-.072
PeakPower/BM(W/k)	.199	.314	.075	-.004	.034	-.145

Note: RF – Rectus Femoris; VL – Vastus Lateralis; Tc – Contraction time; Dm – Muscle displacement; Td – Delay time.

**DISCUSSION**

This is the first study to investigate the validity of TMG assessment as a method of identifying and distinguishing performance differences between elite sprint and endurance track cyclists. Although previous research has compared TMG variables with jumping performance in athlete and non-athlete populations, this was the first study to incorporate the use of force plate providing in depth insight into force production characteristics. Overall, these findings show the TMG method of muscular contractile property assessment should not be used to identify the different performance characteristics between sprint and endurance cyclists, with the only clear parameter displaying a disparity between athlete groups being radial muscle belly displacement. Unlike the TMG, the CMJ assessment clearly identified performance differences between the two groups of athletes in all parameters.

*Reliability of TMG Variables*

The results indicate that for RF measurements, that although variability was high Tc, Ts, Dm and Td were the most reliable variables. For assessment of the VL, Tc, Dm and Td were the variables that displayed the most significant reliability. The ICC for all variables were similar to previous studies which both focused on quadriceps muscle assessment [16, 117]. Both studies reported similar ICC's for Dm (0.97, 0.99), Tc (0.92, 0.98) and Td (0.86, 0.89) as found in the current investigation. The CV's reported in the current study were high, with no variables displaying an optimal CV percentage. Td was the only variable demonstrating acceptable coefficient of variation for both RF (8.89%) and VL (6.88%). The Ts and Tr variables displayed particularly higher CV's than the other variables, which has been identified in previous literature (16, 18). Therefore, together with the findings from previous research the results from the current investigation

suggests that the Tr and Ts parameters are far too unreliable and unrepeatable to be used for athlete monitoring or testing.

*Differences in TMG variables between Sprint and Endurance Track Cyclists*

No TMG variables were significantly different between sprint and endurance track cyclists. However, Dm of the RF was the only TMG parameter that displayed a notable difference between endurance and sprint cyclists; with the sprint athletes showing an 18.61% greater in radial muscle belly displacement in the RF compared to endurance cyclists. The greater muscle displacement observed in the RF of the sprint compared to endurance cyclists may be related to the greater force generating demands of sprint cycling compared to endurance. Muscle coordination, magnitude and orientation of the force, and pedalling rate, significantly influence cycling performance [19, 20]. In-depth EMG analysis has identified that the work proceeded by the lower-limb muscles mainly the RF directly influences these key components of cycling performance [21].

*CMJ Variables between Sprint and Endurance Track Cyclists*

A countermovement jump test is a commonly used assessment of lower-body muscle function in athlete populations. The established research on the CMJ demonstrates the well-known relationship between CMJ performance and maximal speed, maximal strength and maximal power [15, 22]. The sprint cyclists displayed greater force producing capabilities than their endurance counterparts across all variables. These differences can be attributed to the demands of the sport. Although cycling does not involve any variation of jumping and has minimal stretch-shortening cycle influence, the countermovement jump as an indirect measure of lower-body force production can still be considered a performance indicator for sprint cycling



performance [23]. Whereas, the TMG method focuses on singular isolated voluntary muscle contractile properties with no coordination or complex motor patterns required.

#### *Relationship between TMG and CMJ Variables*

When discussing the correlation between TMG results and CMJ performance, there were no significant relationship. This finding aligns with previous research in a study of Brazilian elite soccer players which identified no correlations between TMG parameters and power-related motor tasks [24]. Although, jumping and cycling are not entirely specific to each other TMG focuses on assessing the muscles contractile properties in isolation, whereas both cycling and jumping require intramuscular coordination to elicit a movement. The measurements obtained from CMJ provide insight into how the muscles of the lower extremity produce force in coordinated movement, which is dissimilar to the TMG. These two assessments appear measurements are assessing different components of muscle function and should not be used interchangeably.

#### CONCLUSIONS

The findings from this study indicate that TMG variables obtained from the RF and VL of elite sprint and endurance track cyclists are highly variable. Sport and exercise scientists' utilising TMG to assess the contractile properties of these muscles should interpret the results with caution. Additionally, the TMG variables that were the most reliable were unable to distinguish between sprint and endurance athletes, whereas the CMJ variables were. This indicates that a sport and exercise scientist who is looking profile the muscle function of cyclists for athlete monitoring or talent identification should use a CMJ rather TMG. Further to the point, there were no significant relationships between CMJ and TMG variables which indicate that these two methods are assessing different aspects of muscle function and should not be used interchangeably for athlete monitoring and identification of underlying muscular qualities that would be of importance for cycling.

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