

# 1 SUPPLEMENTAL MATERIALS

## 2 APPENDIX A

### 3 Detailed methodology for the assessment of the neuromuscular function

#### 4 A.1 Countermovement jumps height

5 For each trial of the CMJ, participants performed a set of 3 jumps (separated by ~10 s) to assess jump height.  
6 CMJs were performed with hands on the hips. The highest value recorded for each set was retained for  
7 further analyses.

8

#### 9 A.2 Maximal torque, voluntary activation and contractile function

10 For all maximal contractions, participants were instructed to extend the knee “as hard as possible”. During  
11 the contraction, the twitch interpolation technique was used to measure the voluntary activation and  
12 contractile function (except after the third match). The interpolated twitch technique included a first  
13 supramaximal 100-Hz doublet that was superimposed when torque reached a plateau (superimposed  
14 doublet), and a second doublet (potentiated doublet) that was delivered at rest two seconds after the maximal  
15 contraction. Stimulation intensity was determined at rest by increasing the stimulation intensity by 10 mA  
16 starting from 30 mA until the twitch torque response plateaued. The 130% of the intensity producing the  
17 greatest peak torque response was used to ensure supramaximal twitch response (average stimulation  
18 intensity =  $181 \pm 28$  mA). For the analysis, the maximal torque achieved during the maximal contraction was  
19 determined as the highest peak torque recorded before the superimposed doublet. Voluntary activation was  
20 calculated using the formula of Strojnik and Komi (1998):

21

$$Voluntary\ activation\ (\%) = 100 - \left[ \frac{Superimposed\ doublet \times \left( \frac{Torque_{pre\ stim}}{Maximal\ Torque} \right) \times 100}{Potentiated\ doublet} \right]$$

22

23 where  $Torque_{pre\ stim}$  is the voluntary torque level just before the stimulation. To minimize measurement error,  
24 all participants that showed <70% of voluntary activation at baseline were discarded (Place et al. 2007).  
25 Changes in potentiated doublet were used as an index of changes in contractile function.

26

#### 27 A.3 Rate of torque development

28 Participants were instructed to extend the knee “as fast and strong as possible” with a focus on fast for all  
29 rapid contractions. The contraction was repeated in case of countermovement or pre-tension, determined by a

30 torque  $\leq 2$  N·m and  $\geq 2$  N·m right before the rapid contraction onset, respectively. The rapid contractions  
31 were also repeated if the force level was  $<70\%$  of the maximal torque measured during the maximal  
32 isometric contraction that preceded the series of rapid contractions (Varesco et al. 2019, 2022). Visual  
33 feedback of torque responses was provided on a computer monitor. The analysis for the rate of torque  
34 development was performed as previously described (Varesco et al. 2019, 2022). Briefly, the best five rapid  
35 contractions were determined based on the peak rate of torque development, i.e. the steepest 10-ms segment  
36 on the force-time curve. These five contractions were averaged for further analysis, while the others were  
37 discarded. For each contraction, a nonlinear least-square model was fitted on the first 200 ms torque data  
38 from the onset. The slope coefficient calculated from the model was used to quantify the rate of torque  
39 development, indicating the rapid force production ability. The onset was automatically defined as the point  
40 at which force raised over the average resting baseline by 2 N·m. This onset was also checked visually by an  
41 experienced investigator.

#### 42 *A.4 Experimental apparatus*

43 Participants sat upright on an isometric chair with the knee and the torque meter rotational axes aligned  
44 (ARS dynamometry, SP2, Ltd., Ljubljana, Slovenia), the hip and the knee positioned at  $90^\circ$  and  $120^\circ$   
45 extension, respectively ( $180^\circ$ =full extension), and the leg attached just above to the malleoli using a non-  
46 compliant strap. Hips and chest were securely strapped to maintain the position during contractions. The  
47 position was recorded and reproduced for each athlete between days. Torque data were sampled at 2 kHz  
48 using a PowerLab system (16/30-ML880/P, ADInstruments, Bella Vista, Australia), and transmitted to the  
49 computer through Labchart 8 interface (ADInstruments). For the electrical stimulations, two self-adhesive  
50 surface electrodes ( $80 \times 130$  mm, Stimex electrodes, Pierenkemper, Wetzlar, Germany) were placed over the  
51 rectus femoris and over the vastus medialis portions to allow the stimulation of the quadriceps femoris  
52 muscle (Zarkou et al. 2017). Electrical stimuli of 2-ms duration and 400 V output voltage were delivered via  
53 a constant-current stimulator (DS7A; Digitimer, Welwyn Garden City, Hertfordshire, UK), similarly to what  
54 was previously reported to improve accuracy in the measured outcomes (Zarkou et al. 2017). The position of  
55 each participant on the chair was registered and reproduced between neuromuscular function evaluations.  
56 The electrodes position was marked on the skin with a permanent marker to be kept consistent between tests.  
57 The performance during CMJs, i.e. jump height, was measured using an optoelectronic system  
58 (OptojumpNEXT, Microgate, Bolzano, Italy) and exported using its native software (Optojump v.1.12.23,  
59 Microgate). The knee-extensors neuromuscular data were analyzed offline using Labchart 8 and exported to  
60 excel (Excel v.2206, Microsoft, Redmond, Washington) and R-studio (v. 2022.07.1.554, Boston, MA) to  
61 perform calculations and statistical analysis.

62

### 63 **Detailed methodology for the assessment of the subjective variables**

#### 64 *A.5 Perception of Fatigue and Effort*

65 The question for the visual analog scale for fatigue was ‘How fatigued are you right now?’, and the anchors  
66 were ‘Not fatigued at all’ and ‘extremely fatigued’. The question of the visual analog scale for effort was  
67 ‘How much effort did you put into performing in the round you just completed?’, and the anchors were ‘no  
68 effort’ and ‘maximal effort’. Data from the visual analog scales were manually measured (from 0 to 10 cm).

69

#### 70 *A.6 Perceived workload*

71 Administering the NASA<sub>TLX</sub> questionnaire involves participants rating each of the six dimensions (Mental  
72 demand, Physical demand, Temporal demand, Effort, Performance and Frustration level) on scales from  
73 “Low” to “High”, or from “Good” to “Poor” in the case of Performance (Hart 2006). The raw score for each  
74 of the six items could be multiplied by the weight obtained from an additional questionnaire to generate an  
75 overall workload score. However, being highly time-consuming, this procedure has been skipped across  
76 several studies.<sup>6</sup> Because participants needed to report to the neuromuscular testing stand as soon as possible  
77 once the bout was over, we administered only the rating questionnaire. Data were obtained for each  
78 dimension of the NASA<sub>TLX</sub> expressed as a scale from 0 to 100, with each one of the 20 squares  
79 corresponding to 5-points. For clarity, data for the item “performance” were reversed, so “0” corresponded to  
80 the worst performance possible and “100” to a perfect performance.

81

### 82 **Detailed methodology for statistics**

#### 83 *A.7 Statistical analysis: model fitting and assumptions*

84 Given the dependence of the data for the participants, a random intercept for participants was built into each  
85 model. The empirical test of the model assumptions was performed via model residuals graphical analysis of  
86 the Q-Q plots, that allowed also the detection of eventual outliers. Shapiro-Wilk test was used to ensure that  
87 the assumption of normality was respected for the residuals and random effects. Simulated residuals  
88 [DHARMA package (Hartig 2018)] were used when adopting glmmTMB. The build models were reduced  
89 when no main effect of time, weapon, sex, or result was observed, accordingly to the Occam razor principle,  
90 and compared using Akaike Information Criteria (AIC). Day-by-day reliability and agreement were  
91 evaluated for CMJ, maximal torque, rate of torque development, voluntary activation and potentiated doublet  
92 (familiarization session data vs. pre-competition data of the testing session; procedures and results are  
93 available in Supplemental Materials 2). Finally, to evaluate if maximal torque and rate of torque  
94 development were linked to voluntary activation, these variables were modelled in the function of all  
95 voluntary activation data obtained (i.e. not filtered for values at rest >70%; detailed analysis and results  
96 presented in Supplemental Materials 3).

97

98 *References Appendix A*

- 99 Hart SG. Nasa-Task Load Index (NASA\_TLX); 20 years later. *Proc Hum Factors Ergon Soc Annu Meet.*  
100 2006;50(6):5. doi:10.1177/154193120605000909
- 101 Hartig F. DHARMA: residual diagnostics for hierarchical (multi-level/mixed) regression models. R package  
102 v. 0.2. 0. <http://www.CRAN.R-Proj.Org>. Published online 2018.
- 103 Place N, Maffioletti NA, Martin A, Lepers R. Assessment of the reliability of central and peripheral fatigue  
104 after sustained maximal voluntary contraction of the quadriceps muscle. *Muscle Nerve.* 2007;35(4):486-495.  
105 doi:10.1002/mus.20714
- 106 Strojnik V, Komi PV. Neuromuscular fatigue after maximal stretch-shortening cycle exercise. *J Appl*  
107 *Physiol.* 1998;84(1):344-350. doi:10.1152/jappl.1998.84.1.344
- 108 Varesco G, Espeit L, Feasson L, Lapole T, Rozand V. Rate of force development and rapid muscle activation  
109 characteristics of knee extensors in very old men. *Exp Gerontol.* 2019;124(June):110640.  
110 doi:10.1016/j.exger.2019.110640
- 111 Varesco G, Coratella G, Rozand V, et al. Downhill running affects the late but not the early phase of the rate  
112 of force development. *Eur J Appl Physiol.* Published online 2022:11. doi:doi.org/10.1007/s00421-022-  
113 04990-8
- 114 Zarkou A, Stackhouse S, Binder-Macleod SA, Lee SCK. Comparison of techniques to determine human  
115 skeletal muscle voluntary activation. *J Electromyogr Kinesiol.* 2017;36:8-15.  
116 doi:10.1016/j.jelekin.2017.05.011

117

118 **APPENDIX B**

119 **Simulated competition: number of athletes that disputed each bout.**

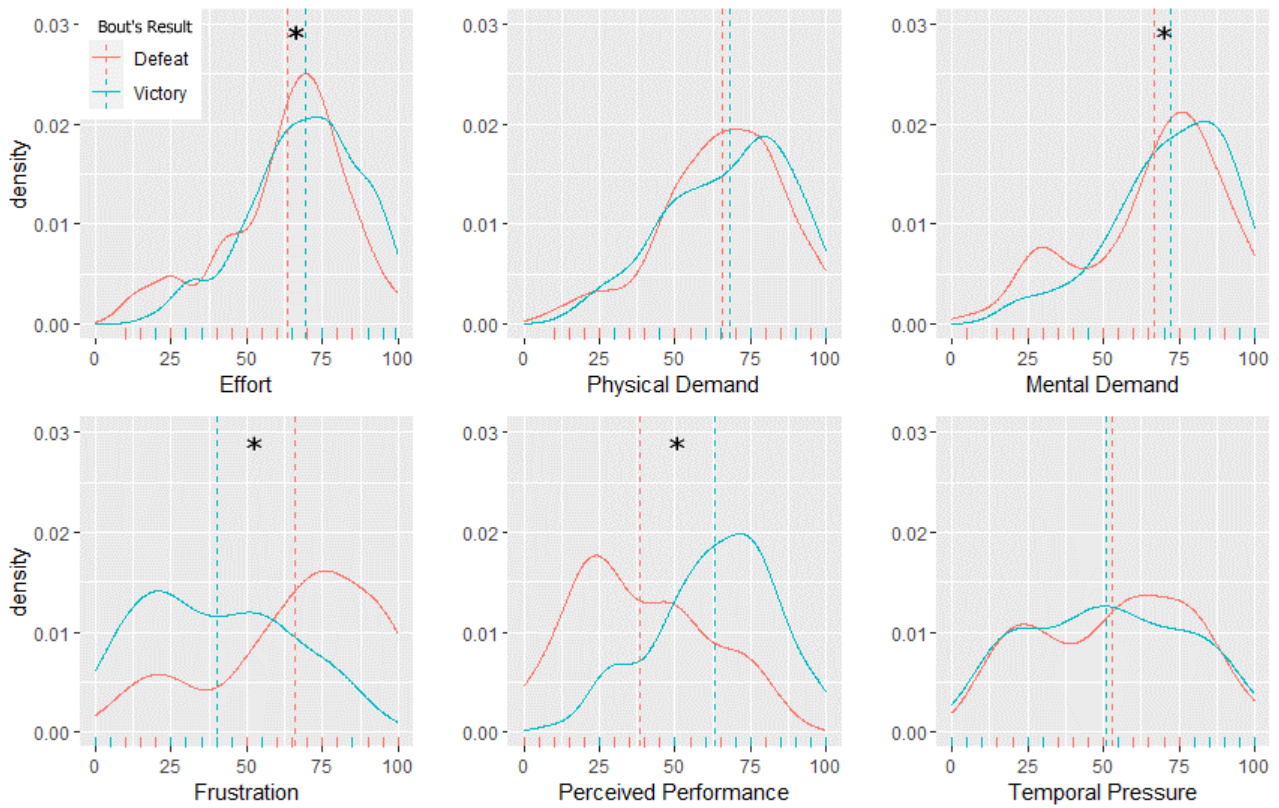
TOTAL = 29 athletes	Bout 1			Bout 2			Bout 3			Bout 4*			Bout 5 <sup>#</sup>		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
<i>Athletes (n)</i>	29	29	15	29	29	13	29	29	15	28	26	11	25	22	7

120 *Notes: \*one athlete did not dispute the 4<sup>th</sup> bout due to pain. #four athletes did not dispute the 5<sup>th</sup> bout due to*  
 121 *pain.*

122

123 **APPENDIX C**

124 **Effect of victory or defeat on the NASA<sub>TLX</sub> dimensions**



125

126 *The estimated density function for each dimension of the NASA<sub>TLX</sub> (all bouts pulled together) separated by*  
127 *the result of the bouts. Dotted lines represent the mean. \*=difference in density distribution between victory*  
128 *and defeat ( $P < 0.05$ ).*

129

130

131 **APPENDIX D**

132 **Reliability analysis and results**

133 Day-by-day reliability and agreement were evaluated for CMJ, maximal torque, rate of torque development,  
134 voluntary activation, and potentiated doublet (familiarization session data vs. pre-competition data of the  
135 testing session) using intra-class correlation coefficients [ICCs (A,1); Two-way mixed model (Koo and Li,  
136 2016); irr package (Gamer et al. 2012)] and coefficients of variation (CVs), respectively, both presented with  
137 95% confidence intervals (95% CI). Based on the ICC estimate, values between 0 and 0.50 were considered  
138 poor, 0.50–0.75 Moderate, 0.75–0.90 good, and >0.90 excellent (Koo and Li 2016). As a rule of thumb, CVs  
139 were considered high and low, respectively, for values greater and lower than 10%.

140 Agreement and reliability for CMJ were high and excellent, respectively [CV = 3% (2%; 4%); ICCA,1 =  
141 0.96 (0.93; 0.98);], being not different between days (P=0.94). Maximal torque was different across days  
142 (P=0.02), being greater during the familiarization session than the day of the bout at baseline ( $313 \pm 64$  N·m  
143 vs.  $275 \pm 61$  N·m), consequently, the agreement was on average low [CV = 11% (8%; 14%)] and reliability  
144 moderate [ICCA,1 = 0.68 (0.07; 0.88)]. The rate of torque development was not different between days  
145 (P=0.05), with low agreement [CV = 15% (10%, 20%)] and moderate reliability [ICCA,1 = 0.50 (0.14;  
146 0.73)]. Agreement and reliability for potentiated doublet were high and good, respectively [CV = 9% (5%;  
147 12%); ICCA,1 = 0.83 (0.66; 0.92);], being not different between days (P=0.88). Voluntary activation was  
148 different across days ( $91 \pm 5\%$  vs.  $84 \pm 6\%$ ; P=0.008), the agreement was high [CV = 6% (3%, 9%)] and  
149 reliability was poor [ICCA,1 = 0.05 (0; 0.45)].

150

151 *References*

152 Gamer M, Lemon J, Fellows I, Singh P. irr: Various coefficients of interrater reliability and agreement  
153 [Computer software]. [Httpwww CRAN R-Proj Org](http://www.CRAN.R-Proj.Org) - package Irr. Published online 2012.

154 Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability  
155 Research. *J Chiropr Med*. 2016;15(2):155-163. doi:10.1016/j.jcm.2016.02.012

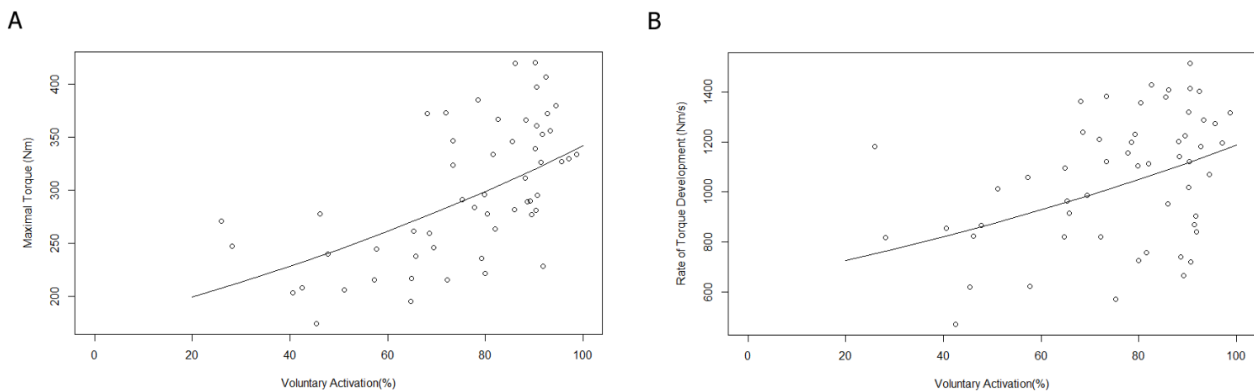
156

157

158 **APPENDIX E**

159 **Association between maximal torque, rate of torque development and voluntary activation**

160 To evaluate if maximal torque and rate of torque development were linked to low voluntary activation,  
161 maximal torque and rate of torque development obtained were modelled in the function of all voluntary  
162 activation data obtained (*i.e.* not filtered for values at rest >70%). We found a significant exponential  
163 function for both maximal torque ( $P < 0.001$ ) and rate of torque development (all  $P = 0.002$ ), and a Pearson's  $R$   
164 coefficients (obtained on log-transformed data) of 0.57 ( $t_{(0,53)} = 5.1$ ,  $P < 0.001$ ; strong correlation) and 0.37  
165 ( $t_{(0,53)} = 2.9$ ,  $P = 0.006$ ; moderate correlation) respectively (figure below). Additionally, potentiated doublet  
166 and voluntary activation were not correlated ( $R = 0.09$ ;  $t_{(0,53)} = 0.6$ ,  $P = 0.52$ ). This would indicate that low  
167 reliability in maximal torque and rate of torque development (see Supplemental Materials 2) was associated  
168 with low voluntary activation in participants, which could be either due to measurement error such as  
169 submaximal volitional effort during contractions (in the case of values <70%, for example) or to a real deficit  
170 in voluntary activation.



171

172