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► To cite this version:

Marc Dauty, Pierre Menu, O. Mesland, Alban Fouasson-Chailloux. Muscle strength particularity of Grand Tour cyclists from knee isokinetic assessment. *Science & Sports*, 2020, 35, pp.82 - 90. <10.1016/j.scispo.2019.10.004>. <hal-03489842>

HAL Id: hal-03489842

<https://hal.science/hal-03489842v1>

Submitted on 22 Aug 2022

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Particularité de la force musculaire des cyclistes de Grands Tours à partir de l'évaluation isocinétique au genou chez.

Short title: Isokinetic strength of Grand Tour cyclists

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Abstract

Objectives: To take part in a Grand Tour, the selection of the cyclists is not easy despite a link between isokinetic knee muscle strength and sprinting power. This study aimed to measure knee muscle strength among professional cyclists and to explore the difference in lower limb force between the rouleur/sprinter and the puncher/climber cycling tactic profiles.

Materials and methods: 39 professional cyclists, who participated in at least one Grand Tour, were assessed at knee level with an isokinetic dynamometer. The relative peak torques normalised to the body mass at the 60, 180 and 240°/s angular speeds and the Limb Symmetry Index, were assessed. Four parameters of the Fatigue testing were studied: total work/kg of extensors and flexors, Fatigue slopes, breakpoint and angle.

Results: All knee extensors isokinetic parameters, excepted extensor LSI, were different between the 2 groups. The best prediction to identify rouleurs/sprinters was found with 2 parameters: knee extensors strength at 240°/s (Odd-ratios: 1440; $p=0.03$) and extensors fatigue slope (ORs: 2.57; $p=0.02$). The Receiver Operating Characteristic curves areas were respectively 0.851 and 0.840.

Conclusion: Isokinetic knee extensors strength and fatigue slope of rouleurs/sprinters are different from those of climbers/punchers. Isokinetic knee extensor's force could represent a new tool to select rouleurs/sprinters for a Grand Tour.

Keywords: Isokinetic; Strength; Sport; Cycling.

Objectifs: Concernant la participation à un Grand Tour, la sélection des cyclistes n'est pas aisée malgré le lien existant entre la force musculaire isocinétique au genou et la puissance au sprint. Cette étude avait pour objectif de mesurer la force isocinétique au genou chez des cyclistes professionnels, afin d'explorer les différences de force musculaire entre les rouleurs/sprinteurs et les puncheurs/grimpeurs.

Matériels and méthodes: 39 cyclistes professionnels ayant participé à au moins 1 Grand Tour ont été évalués au niveau du genou par un dynamomètre isocinétique. Les pics de force rapportés aux poids ont été évalués à la vitesse angulaire de 60, 180 et 240°/s, ainsi que l'index de symétrie des membres (LSI). Quatre paramètres du test de fatigue ont été évalués : travail total/kg des extenseurs et fléchisseurs, pentes de fatigues, point d'arrêt et angle.

Résultats: Tous les paramètres isocinétiques, excepté le LSI des extenseurs, étaient différents entre les 2 groupes. La meilleure prédiction pour identifier les rouleurs/sprinteurs était retrouvée pour 2 paramètres: la force des extenseurs au genou à 240°/s (odds-ratio: 1440; $p=0.03$) et la pente de fatigue des extenseurs (odds-ratio: 2.57; $p=0.02$). Les aires sous la courbe ROC étaient respectivement de 0.851 et 0.840.

Conclusion: La force isocinétique des extenseurs du genou et la pente de fatigue des rouleurs/sprinteurs sont différentes de celles des puncheurs/grimpeurs. La force isocinétique au genou pourrait représenter un nouvel outil pour sélectionner les rouleurs/sprinteurs pour un Grand Tour.

Keywords: Isocinétique; Force; Sport; Cyclisme.

1. Introduction

Major European professional cycling stage races, the Tour de France, the Giro d'Italia and the Vuelta a España, consist of daily stage races that are reiterated over a period of 3 weeks [1]. Some stage races are practiced on flat roads so that some cyclists can stand out from the others thanks to their sprinter qualities. Drafting helps the best sprinters (riders who can finish a race very explosively by accelerating quickly to a high speed) to follow the rouleurs (riders who are particularly successful in individual or in team timed races). Road cyclists must be able to achieve 20 to 70 maximum efforts of about 10 seconds each during races [2]. Other hilly or mountain races require aerobic qualities [3–5]. Climbers ride especially well on very highly inclined roads such as mountains and punchers are more specialised in hill races. Thus, a professional team of 8 or 9 cyclists engaged to perform in a Grand Tour, includes one sprinter and one climber, and in variable proportions rouleurs and punchers according to the general tactics determined by the Sports Director. Although it seems easy to differentiate sprinters from climbers during preparation races, the selection of the cyclists is not always easy because many rouleurs are also able to sprint and punchers to climb. However, physiological parameters regularly measured in the laboratory could help this selection [1,4,6]. The prediction of the performance is possible from several parameters such as the maximum power normalised to body weight ($> 5,5$ W/kg), the distribution of quadriceps muscle fibers from biopsy and the blood lactate concentration collected during maximal exercise [7–9]. These parameters are not easy to measure, are expensive and require time. In addition, power production on a bicycle depends on the cyclist's age and experience, the bicycle setting (the position of the saddle) and the bicycling cadence (≈ 120 rpm)[10,11]. More than 70% of the bicycling power depends on knee extensors and flexors strength [12,13]. In young cyclists, a significant link exists between power measured by the 30-second Wingate Test and knee extensors and flexors isokinetic strength [14]. More recently, this relationship

was confirmed between knee extensors isokinetic strength and the maximum and average power over 10 seconds measured during a sprint in sitting position [15].

According to these results, we hypothesised that rouleurs/sprinters present different muscular profiles compared to punchers/climbers. We aimed to measure these muscular profiles with knee isokinetic dynamometer.

2. Method

2.1 Sample

Forty-five professional male cyclists were systematically evaluated at the beginning of the sport season in the Sports Medicine department of the Nantes University Hospital. Six cyclists were excluded because knee isokinetic measurement was performed in a post-traumatic context: 2 cases of lower limb fracture, 1 case of back pain and 3 cases of anterior knee pain. Thirty-nine were included because they had taken part in at least one Tour of France, one Giro d'Italia or one Vuelta a España, testifying of their very high sport level. The cyclists' profiles were established by the Sports Director and the coach of the cycling teams at the time of isokinetic measurements. Two groups were defined: one consisting of 24 rouleurs/sprinters (17 rouleurs and 7 sprinters) and another one of 15 puncher-climbers (8 punchers and 7 climbers). Ethics approval was obtained from the internal review board of the professional cyclist team and from the ethical committee of the Sport Medicine Regional Institute of Nantes. All performance data were anonymised before analysis to ensure participant confidentiality.

2.2 Isokinetic assessment

After a 10-minute cyclo-ergometer warm up, isokinetic strength tests were performed using a Cybex Norm[®] dynamometer (Lumex Inc. Ronkonkoma, NY, USA). The quadriceps and

hamstring torques were gravity-corrected and the dynamometer calibration was performed in accordance with the manufacturer instructions. The two knees were evaluated in a random order after instruction and with verbal encouragements and no visual feedback. After familiarization with the isokinetic movement, the cyclists were tested with 3 repetitions of concentric knee extension and flexion at 60°/sec, followed by 5 concentric repetitions at 240°/sec [16]. Finally, they performed 30 concentric repetitions at 180°/sec (isokinetic Fatigue test)[17]. Recovery between every series was 30 seconds of rest. Several isokinetic parameters were taken into consideration:

- Relative peak torque defined by the maximal peak torque normalised to the body mass (Nm/kg) at all the 3 angular speeds (60, 180 and 240°/s).
- Isokinetic Fatigue parameters: Relative knee extensors and flexors total work normalised to body mass (J/kg), knee extensors Fatigue slopes (degrees) [18], breakpoint (defined by the number of contractions before the inflexion point of the fatigue curve) and angle (aBP in degrees between the two phases defined by the breakpoint) [19] (Figures 1a and 1b). The choice of these Fatigue parameters was justified because the Fatigue slope and the number of contractions to obtain the breakpoint of knee extensors are negatively correlated with the type 2b muscle fiber percentage of the vastus lateralis muscle [19]. In addition, the Fatigue slope and the knee extensors total work (Isokinetic Fatigue test of 30 x 180°/s) are associated with the peak power output measured during a Wingate anaerobic test [20]. All the 30 repetitions done at 180°/s were considered and data from both left and right knees were averaged. The relative reliability of the isokinetic Fatigue parameters established by intra-class correlation coefficient (ICC) was acceptable for the knee extensors slope and total work (ICC: 0.56 to 0.91) [17,21]. In our cyclist group (n=13), the 7-day test-

to-test reliability by ICC was 0.85 [0.54-0.95] and 0.73 [0.41-0.92] for the total work of knee extensors and flexors, respectively.

- Limb Symmetry Index (LSI) (weak limb/strong limb): Quadriceps-to-quadriceps ratio and Hamstring-to-hamstring ratio (%) for all the 3 angular speeds [22]. LSI was calculated in order to obtain results < 1 . LSI has an excellent reliability of 0.95, established for the knee muscle peak torque by ICC [23]. The reliability for the LSI was better for the Quadriceps-to-quadriceps ratio than the Hamstring-to-hamstring ratio (ICC: 0.78 and 0.59 respectively) [23].

2.3 Statistical analysis

The statistical analysis was performed with SPSS 23.0® software (IBM corp. Dublin, Ireland). Univariate analysis (independent t-test after variances analysis by Levene's test) and χ^2 test were used to compare quantitative and multinomial data of Rouleurs/Sprinters and Punchers/Climbers. No comparison was made between sub-groups in accordance to the tactical profile (rouleur, sprinter, puncher and climber) because of the insufficient number of cyclists. The results were considered significant at the 5% critical level ($p < 0.05$).

The prediction of road cyclist profile was assessed using a stepwise binary logistic Wald's regression (inclusion probability ≤ 0.10) and ROC curve (Receiver Operating Characteristics curve). Logistic regression function predicts a logit transformation of the probability of the road cyclist profile of the form $\text{odds} = \text{probability}/(1-\text{probability})$ [24]. In this study, the choice was to present the potential profile of the rouleur/sprinter road cyclist. The measured parameters were used for the regression model taking into consideration the leg as a unit and the calculated LSIs were used taking into consideration the cyclists as units [25]. At the beginning of the logistic regression, the baseline model correctly classifies the percentage of participants based on the more frequent category. From the final equation including the

predictive parameters, the model prevision can classify the percentage of subjects in the good category. Because of continuous quantitative parameters, the odds ratios (ORs) were estimated from the exponential of the coefficient B of the logistic regression[25]. The Hosmer-Lemeshow test was used to know if data fitted the model well. The R-squares of Cox-Snell and Nagelkerke (% of the variance explained by the predictors) were used to assess 'the goodness of fit' of the model. The ROC curve and its area were interpreted as excellent (0.9-1), good (0.8-0.9), fair (0.7-0.8), poor (0.6-0.7), or failed (0.5-0.6) [26]. Predictive strength values were done for 100, 95 and 80% specificity and likelihood ratios were calculated [27]. The higher the positive likelihood ratio was, the better the parameters could distinguish rouleurs/sprinters from punchers/climbers. The weaker the negative likelihood ratio was, the better the absence of parameters could differentiate Rouleurs/Sprinter groups from Puncher-climber ones.

3. Results

Thirty-nine professional cyclists were included. During their careers, they had participated in 305 Grand Tour races, 185 Tour de France, 61 Vuelta a España and 59 Giro d'Italia. Their average age was 25 +/- 4 years [21-36] with a weight of 70.9 +/- 5.4 kg [62-82] and a height of 179 +/-5 cm [169-191] at the time of isokinetic measurements. The comparison of the measured and calculated parameters between rouleurs/sprinters and punchers/climbers is shown in Tables 1 and 2.

Univariate analysis showed that the relative peak torque normalised to the body mass for the 3 explored isokinetic velocities and the Fatigue test parameters of knee extensors, predicted the Rouleur/Sprinter profile (Table 3). However, the strength parameters of the knee flexors and the total work of the knee flexors, as well as the LSI parameters, were not predictive.

A model was established by binary logistic regression with 2 independent parameters: knee extensors strength at 240°/s and extensors Fatigue slope. Odds ratios are presented in Table 4. The percentage of correct hazard classification was 61.5% and the prevision by the model was 82.1%. Data fitted the model well (Hosmer-Lemeshow test; $p = 0.70$) and the model was well adjusted (R-squares of Cox-Snell and Nagelkerke of 0.442 or 0.601 respectively). The ROC curve area was 0.851 [95%CI: 0.724-0.979] for knee extensors strength at 240°/s and 0.840 [95%CI: 0.714-0.966] for extensors Fatigue slope. According to the ROC curve, cut-off values could be defined. Any professional cyclist presenting knee extensors strength at 240°/s of at least 1.76 Nm/kg and an extensor fatigue slope under or equal to 7 degrees, had a rouleur/sprinter profile (Table 5). Four cyclists presented this profile, 2 sprinters (2.05 and 1.96 Nm/kg / slope: 9 et 8° respectively) and 2 rouleurs (1.91 and 1.83 Nm/Kg / slope 8° et 9° respectively). The breakpoint, the knee flexors strength and the work or the LSI parameters were not predictive.

4. Discussion

No previous study had been interested in the profile of professional cyclists according to their tactical role in a professional team participating in a Grand Tour. However, isokinetic measurement showed very different muscular profiles between rouleurs/sprinters and punchers/climbers. Moreover, this strength evaluation is very safe because of isokinetic movement, contrary to a measure on road or in competition, where the risk of falls is always present [28]. In less than 30 minutes, for a fairly low cost, without causing excessive fatigue and without the need of blood sampling, the peak torque measurement of knee extensors at 240°/s and the Fatigue test completion are sufficient to properly classify 82.1% of cyclists.

Some scientific evidence corroborates our results even though only one study reported knee isokinetic results among cyclists [15]. The lack of data concerning isokinetic strength in this sport is probably due to the importance of aerobic and mental qualities indispensable to a Grand Tour achievement [5,29,30]. In fact, the link between lower limb isokinetic strength and maximum pedaling power remains poorly known even if, recently, it has been shown that a combination of isometric knee strength and sprint training improves sprint maximum power [31]. Significant correlations, between sprint maximal power and isokinetic strength of knee extensors normalised to the body weight and evaluated at several isokinetic velocities (r from 0.53 to 0.67), have been shown [15]. The correlation was higher when the angular velocity increased from 60-180 to 240 °/s [15]. That was consistent with our results to identify the rouleurs/sprinters with an odds ratio which increased with isokinetic angular velocity (Table 3). In addition, Rannama et al. had shown that their six most powerful sprinter cyclists had a greater isokinetic strength compared to the six less powerful [15]. The peak torque at 240°/s was 2.02 +/- 0.22 Nm/kg versus 1.68 +/- 0.19 Nm/kg ($p=0.01$) in a sample of 17 cyclists [15]. These values were greater than those we have measured (1.66 +/- 0.17 Nm/kg for rouleurs/sprinters). This suggests that they may have included only sprinters. It was also reported that knee flexors strength was not related to power. Our results concerning the isokinetic strength of knee flexors were similar since this parameter did not identify the most powerful cyclists that are the rouleurs/sprinters.

According to isokinetic Fatigue test, several original predictive parameters have been highlighted. The breakpoint was present only for knee extensors. According to Gerdle et al., the higher the number of repetitions required to obtain the breakpoint is, the lower type 2b muscle fibre percentage of vastus lateral is [19]. Thus, this point could reflect the anaerobic characteristics of a subject. Specifically, when the breakpoint was present at the 6th repetition, just over 6 seconds were required to move 6 times the 100 degrees of knee extension and

flexion at 180°/s isokinetic speed. The breakpoint determination could reflect anaerobic abilities of a rouleur/sprinter cyclist. Conversely, the breakpoint could not be determined in 45% of the rouleurs/sprinters (Table 6), which could be the sign of excellent aerobic abilities. Indeed, breakpoint is only identified after 40 repetitions for 100-repetitions 90°/s Fatigue test in healthy subjects [19]. The 30-repetitions 180°/s Fatigue test, we used, may have been insufficient to highlight the Breakpoint of cyclists with excellent aerobic qualities. Another reason could be the fact that an isokinetic speed of 90°/s is more challenging than a 180°/s one.

The angle defined by the two breakpoint phases was significantly greater in rouleur/sprinter cyclists. However, this angle depends on the breakpoint according to its definition (Fig 1A). Because of the impossibility of measuring this angle in more than half of the group, this result is not generalizable. It would only present an individual interest in some rouleurs or sprinters. The variability of this angle during a sport season is unknown.

The Fatigue slope has shown a greater interest because of its contribution to the model prediction. Indeed, higher the slope is, the more the cyclist has a sprinter profile. A slope measured at more than 7 degrees was specific to the Rouleur/Sprinter profile with a sensitivity of 30%. This slope, as the knee extensors total work measured during the Fatigue test, reflects the anaerobic aptitudes because of the correlations shown with the Wingate test ($r = 0.85$) [14,20]. On the contrary, the knee flexors total work is not associated with the work measured in the Wingate test ($r = 0.09$) [20]. Our results are consistent because the total knee flexors work does not predict a cyclist profile.

Finally, the various calculated Limb Symmetry Indexes did not allow us to identify cyclist profiles.

Despite an excellent model of prediction to assess professional cyclist profiles, some limitations have to be mentioned. The application of this study is limited to professional

cyclists that race at very high levels (e.g., Tour de France, Giro d'Italia, Vuelta a España) that most likely already possess other indispensable attributes, such as high aerobic capacity and mental endurance. Moreover, the present study only identifies how professional athletes are categorised and does not predict whether a developing athlete will one day be classified in one of these categories. The low number of 39 subjects did not enable us to identify distinctly the 4 sub-groups of cyclists (sprinters, rouleurs, punchers and climbers). However, the rouleur profile is very close to that of sprinters. Similarly, the puncher profile is also very close to that of climbers. So, we may doubt whether a larger sample of cyclists studied might have significantly identified these 4 sub-groups. In addition, the number of cyclists was limited because of the inclusion criterion which required the participation in at least one Grand Tour. The cyclist profile was determined by the Sports directors and coaches without our knowing the degree of subjectivity of this classification. So, a generalization of our study's findings to other investigations is limited due to the subjective nature of the classification of the participants. However, it was reasonable to assume that these cyclists over 25, were well known to their coaches because of their objective performances obtained during cycling races. Finally, isokinetic knee flexion-extension movement does not correspond to pedaling. However, this movement is a good approximation due to the moment of force measured through a knee amplitude of 100 degrees, which is close to the range of motion necessary to achieve a pedal turn ($\approx 110^\circ$) [32]. If the pedaling rate is 90 revolutions per minute for example, that is to say 1.5 turns per second, the knee extension is achieved in 0.33 seconds, at an average angular velocity close to $300^\circ/\text{s}$, slightly higher than the predictive speed of $240^\circ/\text{s}$ correlated to sprint [15]. In an evaluation with an isokinetic speed of $240^\circ/\text{s}$, the movement is performed at a constant velocity (isokinetic) only 65% of the range of motion [33]. Beyond this speed, it is not an isokinetic movement anymore because at 360 and $450^\circ/\text{s}$, the isokinetic component is only 48 and 18% of the range of motion, respectively. It is due to the reciprocal

nature of the knee flexion-extension, which requires changes of direction with accelerations and decelerations [33].

Isokinetic knee extensors strength and fatigue slope can identify rouleurs/sprinters from climbers/punchers in professional Grand Tour cyclists. In professional cycling team, isokinetic knee evaluation may help the selection of cyclists according to their tactical profiles, in order to take part in a Grand Tour.

5. Conclusion

Isokinetic measurements have enabled us to differentiate the rouleurs/sprinters from the punchers/climbers thanks to the knee extensors peak torque normalised to the body weight at 240 °/s and the Fatigue slope. These results are quickly and safely obtained, without excessive fatigue for professional cyclists. Thus, knee isokinetic strength evaluation could give new information to help the selection of cyclists thanks to their tactical profiles, in order to take part in a Grand Tour with a professional cycling team.

Disclosure statement

The authors have no conflict of interest to report.

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Table 1. Comparison of measured isokinetic parameters between rouleurs/sprinters and punchers/climbers (average +/- one standard deviation) and sub-groups details (mean values)

Measured Parameters	Rouleurs/sprinters (Rouleur / Sprinter)	Punchers/climbers (Puncher / Climber)	<i>p</i>
Age (Year)	25 +/- 3 (25.2 / 25.7)	25 +/- 5 (25.2 / 25.5)	0.90
Mass (Kg)	73.1 +/-5 (73.8 / 71.2)	66.8 +/- 3.2 (68/ 65.4)	<0.001
Height (cm)	180 +/- 5 (181 / 176)	177 +/- 4 (176 / 177)	0.10
KE60 (Nm/kg)	2.91 +/- 0.31 (2.87 / 3.01)	2.62 +/- 0.31 (2.62 / 2.62)	<0.01
KE180 (Nm/kg)	1.93 +/- 0.17 (1.91 / 1.98)	1.73 +/- 0.17 (1.71 / 1.76)	<0.001
KE240 (Nm/kg)	1.66 +/- 0.17 (1.65 / 1.68)	1.44 +/- 0.15 (1.42 / 1.46)	<0.001
KF60 (Nm/kg)	1.76 +/- 0.18 (R:1.78/S:1.71)	1.66 +/- 0.25 (P:1.66/C:1.65)	0.15
KF180 (Nm/kg)	1.38 +/- 0.21 (1.41 / 1.30)	1.31 +/- 0.29 (1.33 / 1.28)	0.29
KF240 (Nm/kg)	1.25 +/- 0.15 (1.26 / 1.22)	1.16 +/- 0.19 (1.20 / 1.11)	0.12
FatKE (J/kg)	54.7 +/- 5.6 (54.7 / 54.8)	50 +/- 5.2 (50.3/ 49.7)	<0.01
FatKF (J/kg)	39.6 +/- 4.9 (40.7 / 37.1)	38 +/- 4.2 (38.7 / 37.3)	0.30
Fat slope (degrees)	6.2 +/- 1.6 (6.1 / 6.5)	4.2 +/- 1.1 (3.8 / 4.7)	<0.001
Fat BP (n contractions)	6 +/- 5 (6.3 / 5.1)	1 +/- 3 (0 / 3)	<0.01
Fat aBP (degrees)	5 +/- 5 (5 / 5.1)	1 +/- 3 (0 / 2.8)	<0.01

KE: Knee extensors; KF: Knee flexors; Fat: Total Work during Isokinetic Fatigue test; Fat slope: Isokinetic Fatigue slope; BP: breakpoint; aBP: angle between the 2 phases defined by the breakpoint

Table 2. Comparison of calculated Limb Symmetry Index between roulers/sprinters and punchers/climbers and sub-groups (average +/- one standard deviation)

Calculated Parameters	Rouleur-sprinter (Rouleur / Sprinter)	Puncher-climber (Puncher / Climber)	<i>p</i>
LSI KE60	0.92 +/- 0.05 (R:0.94 / S:0.91)	0.95 +/- 0.05 (P:0.94 / C:0.95)	0.15
LSI KE180	0.93 +/- 0.04 (R:0.93 / S:0.92)	0.93 +/- 0.08 (P:0.95 / C:0.91)	0.91
LSI KE240	0.93 +/- 0.03 (R:0.93 / S:0.93)	0.93 +/- 0.08 (P:0.94 / C:0.91)	0.99
LSI KF60	0.93 +/- 0.04 (R:0.91 / S:0.97)	0.92 +/- 0.05 (P:0.93 / C:0.91)	0.38
LSI KF180	0.91 +/- 0.08 (R:0.90 / S:0.94)	0.90 +/- 0.09 (P:0.93 / C:0.87)	0.63
LSI KF240	0.91 +/- 0.07 (R:0.90 / S:0.92)	0.91 +/- 0.08 (P:0.91 / C:0.91)	0.94
LSI Fat KE	0.94 +/- 0.04 (R:0.94 / S:0.93)	0.91 +/- 0.09 (P:0.93 / C:0.89)	0.14
LSI Fat KF	0.90 +/- 0.07 (R:0.87 / S:0.93)	0.88 +/- 0.07 (P:0.91 / C:0.86)	0.52

LSI: Limb Symmetry Index; KE60: Knee extensors at 60°/s; KF: Knee flexors; Fat: Total Work during Isokinetic Fatigue test.

Table 3. Univariate analysis to predict the sprinter/rouleur profile with ORs calculated from the regression coefficient B and ROC area.

	B	ORs	95% CI	p	ROC a	95% CI
KE60 (Nm/kg)	3.761	43	1.89 – 987	0.01	0.751	0.595 - 0.907
KE180 (Nm/kg)	7.033	1134	7.28 – 176694	0.006	0.792	0.632 - 0.952
KE240 (Nm/kg)	9.871	19374	22.1 – 16970249	0.004	0.851	0.724 - 0.979
FatKE (J/kg)	0.157	1.17	1.02 – 1.34	0.02	0.717	0.554 - 0.880
Fat slope (degrees)	0.193	3.30	1.52 – 7.15	0.002	0.840	0.714 - 0.966
Fat BP (n contractions)	0.190	1.21	1.03 – 1.41	0.01	0.714	0.550 - 0.877
Fat aBP (degrees)	0.198	1.22	1.06 – 1.46	0.02	0.688	0.515 - 0.860

B : regression coefficient B ; ORs: Odds ratios; KE60: Knee extensors at 60°/s; KE180: Knee extensors at 180°/s; KE240: Knee extensors at 240°/s; Fat: Total Work during Isokinetic Fatigue test; Fat slope: Isokinetic Fatigue slope; BP: breakpoint; aBP: angle between two phases defined by the breakpoint; ROC a: ROC curve area; 95% CI: 95% Confidence Interval.

Table 4. Variables modelling the sprinter-rouleur profile from the binary logistic regression analysis

	<i>B</i>	ORs	95% CI	<i>p</i>
Fat slope (degrees)	0.862	2.57	1.11-5.92	0.026
KE240 (Nm/kg)	7.272	1440	1.67- 1240855	0.035

B: regression coefficient *B*; ORs: Odds ratios; KE240: Knee extensors at 240°/s; Fat slope: Isokinetic Fatigue slope; 95% CI: 95% Confidence Interval.

Table 5. Characteristics of strength predictive parameters for Rouleur/Sprinter's profile

Strength parameter values	Specificity %	Sensitivity %	Positive likelihood ratio	Negative likelihood ratio
KE60				
3.20 Nm/kg	100	20.8	—	0.79
2.92 Nm/kg	95	37.5	7.5 **	0.65
2.84 Nm/kg	80	50	2.5*	0.62
KE180				
2.11 Nm/kg	100	12.5	—	0.87
2.05 Nm/kg	95	16.7	3.34*	0.87
1.86 Nm/kg	80	62.5	3.12*	0.46*
KE240				
1.76 Nm/kg	100	29.2	—	0.71
1.69 Nm/kg	95	41.5	8.3**	0.61
1.54 Nm/kg	80	70.8	3.54*	0.36*
FatKE				
60 J/kg	100	20.8	—	0.79
58.3 J/kg	95	41.7	8.34**	0.61
50.6 J/kg	80	75	3.75*	0.31*
Fat slope				
7 degrees	100	29.2	—	0.71
5.5 degrees	80	75	3.75*	0.31*

KE60: Knee extensors at 60°/s; KE180: Knee extensors at 180°/s; KE240: Knee extensors at 240°/s; Fat: Total Work during Isokinetic Fatigue test; Fat slope: Isokinetic Fatigue slope.

Positive likelihood ratio: *the parameter is sometimes useful or **often useful.

Negative likelihood ratio: *the absence of the parameter is sometimes useful.

403 **Figure captions**

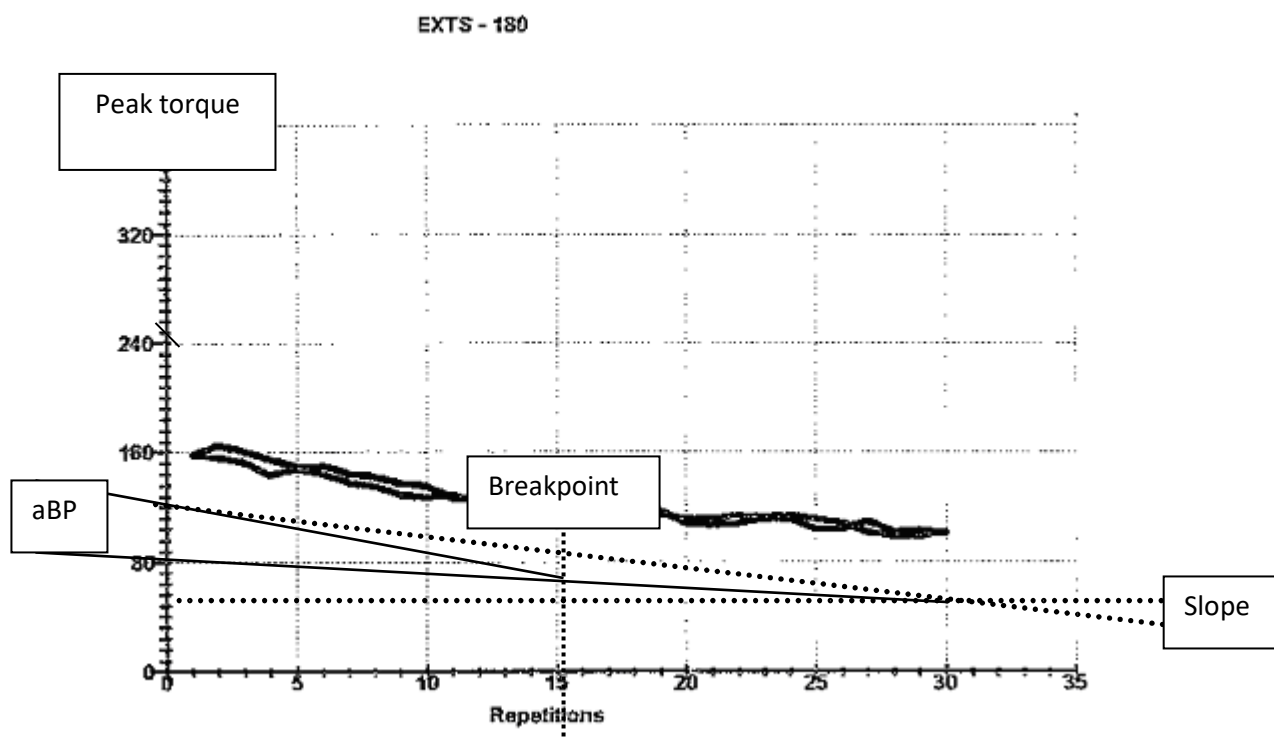
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405 **Figure 1a and 1b:** Isokinetic knee extensors Fatigue test (30x180°/s): Fatigue slope,
406 Breakpoint and aBP (angle between the two phases defined by the breakpoint).

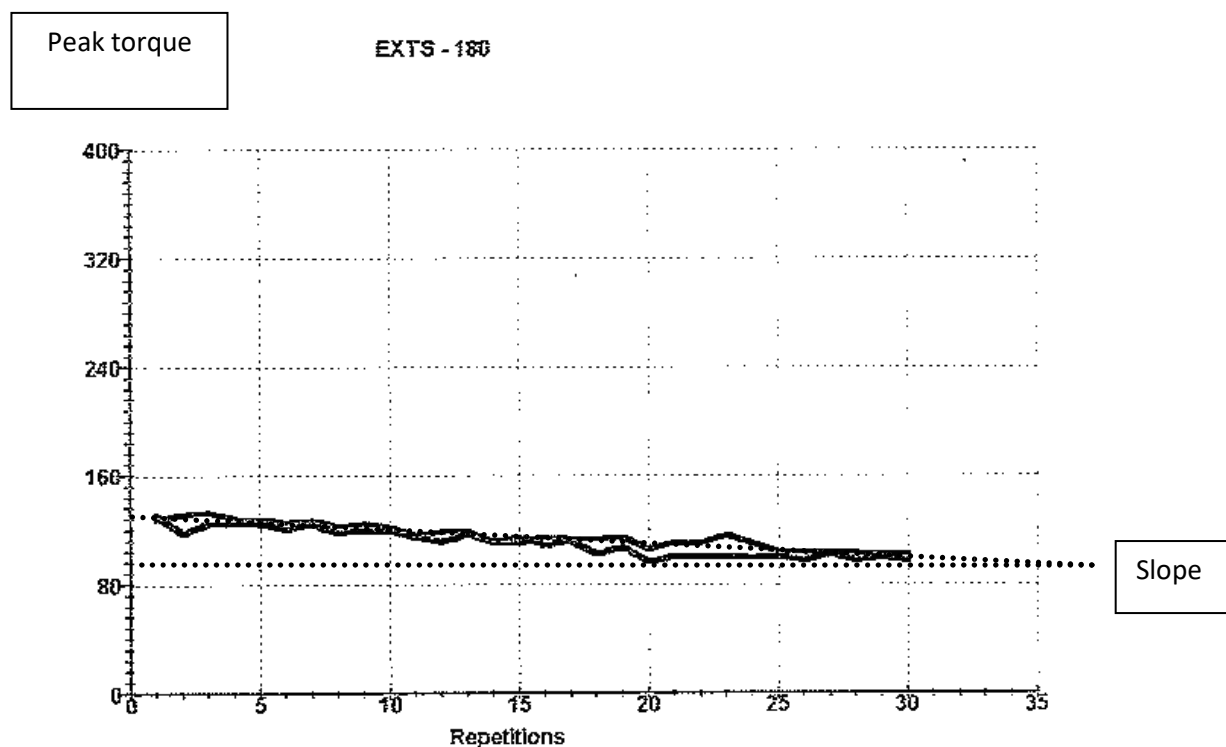
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408 1a: Sprinter profile: Slope: 6°; Breakpoint (number of contractions: 15) and aBP: 8°

409 1b: Climber profile: Slope: 4°; Breakpoint (number of contractions: 0) and aBP: 0°



A: Sprinter profile: Slope: 6° ; Breakpoint (number of contractions: 15) and aBP: 8°



B: Climber profile: Slope: 4° ; Breakpoint (number of contractions: 0) and aBP: 0°