

Assessment of Tug of War pullers' competition intensity and physiological response at the 2019 European Championship

Evaluación de la intensidad de competición y la respuesta fisiológica de los tiradores en el Campeonato de Europa 2019

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Abstract. Tug of war (TOW) involves 2 teams of eight people, pulling against each other on a rope. The main goal of TOW is to pull the opposing team towards a centre line over a distance of 4 m. The measurement of physiological parameters is key to understanding the demands of an activity and to identifying its limiting performance factors. The main aim of this study was to evaluate the intensity and effort demands of TOW pullers during competition, as follows: Data were collected from 7 male pullers (Height: 175.14 ± 4.85 ; Body Mass: 77.39 ± 3.92 ; Age: 39.86 ± 11.68 ; %Fat: 17.56 ± 5.21 ; VO_{2max} : 44.24 ± 8.38) in the 560 kg category. The blood lactate concentrations (LAC) were assessed before and at the end of each pull, and the global rating of perceived exertion (RPE) at the end of the pulls. The following week, pullers performed a graded exercise test (GXT). Heart rate, LAC and RPE were assessed before, during and at the end of the GXT to calculate the individual anaerobic threshold. The mean blood lactate concentrations recorded at the end of the pulls (6 ± 1.9 mmol/l) were 32% higher than the mean values recorded for the individual anaerobic threshold intensity (4.1 ± 0.5 mmol/l). For their part, the mean RPE values of athletes after the pulls (6 ± 1.5 mmol/l) were 21% lower than those obtained for intensity of the individual anaerobic threshold (7.6 ± 0.8 mmol/l). The intensity and effort response are greater and kept above the anaerobic threshold during the competition in TOW pullers.

Key Words: Tow, blood lactate, RPE, physiological, intensity.

Resumen. Tug of war (TOW) involucra a 2 equipos de ocho personas, tirando una contra la otra con una cuerda. El objetivo principal es llevar al equipo contrario hacia una línea central a una distancia de 4 m. La medición de parámetros fisiológicos es clave para comprender las demandas de una actividad y para identificar sus factores limitantes de rendimiento. El objetivo principal de este estudio fue evaluar la intensidad y las demandas de esfuerzo de los tiradores de TOW durante la competición. 7 tiradores masculinos (altura: $175,14 \pm 4,85$; masa corporal: $77,39 \pm 3,92$; edad: $39,86 \pm 11,68$; % de grasa: $17,56 \pm 5,21$; VO_{2max} : $44,24 \pm 8,38$) en la categoría de 560 kg. Se evaluaron concentraciones de lactato (LAC) antes y después de cada tirada, y el esfuerzo percibido (RPE) al final. La siguiente semana, los tiradores realizaron una prueba de esfuerzo (GXT). La FC, LAC y RPE se evaluaron antes, durante y después del GXT para calcular el umbral anaeróbico individual. Las concentraciones de LAC registradas medios registrados para la intensidad del umbral anaeróbico individual (VT_2) ($4,1 \pm 0,5$ mmol/l). Los valores medios de RPE de los deportistas en competición ($6 \pm 1,5$ mmol/l) fueron un 21% inferiores a los obtenidos para la intensidad del VT_2 ($7,6 \pm 0,8$ mmol/l). La intensidad y la respuesta al esfuerzo son mayores y se mantienen por encima del VT_2 durante la competición en tiradores TOW al final de los tirones ($6 \pm 1,9$ mmol/l) fueron un 32% más altas que los valores.

Palabras clave: Tow, lactato, RPE, fisiología, intensidad.

Introduction

Tug of war (TOW) involves two teams of eight people, pulling against each other on a rope. The main goal is to pull the opposing team towards a centre line over a distance of 4 m (TOW, 2021). Typically, matches are decided over the best of three pulls. During either

dynamic or static pulling in a TOW competition, the maximal pulling force on the rope might be higher than 150% of the participants' body mass (Tanaka, Ushizu, Minamitani, Fukushima & Yamamoto, 2005). Analysing the type of actions from an energy point of view, based on duration of the pulls, confirms that they are mainly oxidative and glycolytic (Astrand, 1979), but as in other team sports, the actions are not of constant intensity, and although the duration of the pulls in TOW on land can reach 20 minutes, the high intensity actions (glycolytic and phosphocreatine metabolism) are of vi-

Fecha recepción: 12-07-21. Fecha de aceptación: 17-11-21

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tal importance. In this sense, Dalmonte (Dalmonte, Gallozi, Lupo & Marcos, 1987) justifies the importance of Glycolytic metabolism in competition as being at 20%. Other scientists such as MacLaren state that it can be considered as moderately aerobic (AE), producing energy and with a frequent coupling of AE and anaerobic energy (ANE). Therefore, it would be important to ascertain the prominence of competing metabolic pathways and to evaluate the possibility of greater use of glycolysis (GL). Margaria and Aghemo (Margaria & Aghemo, 1971) used the determining of Blood Lactate Concentration (LAC) following exercise to measure the amount of energy released through the ANE pathway, although this method is subject to some difficulties: the first is to identify where there is a balance between the LAC that we analyse and the lactic acid existing in the muscle, this being difficult to diagnose when it comes to maximum exercise. The second is the great variability in the LAC dilution space (depending on many factors that are difficult to control, among them the greater or lesser hydration level of the athlete). The next is the high LAC recycling rate, insofar as before the muscle LAC has been balanced with LAC in the blood, a large fraction of it will have been metabolized in the muscle itself and in others, in the liver or in the heart. And in the end LAC can also be produced during GL via the accumulation of pyruvate (PV), which activates the enzyme Lactate dehydrogenase (LDH) and converts it into lactate. The assessment of LAC is a common practice in many sports with a view to establishing an approximation of athletes' training intensities (Bishop, Smith & Kime, 1992). However, to the best of the author's knowledge, no previous data related to LAC values have been published in terms of TOW.

On the other hand, the heart rate (HR) variable in the field of sports sciences has been proposed for the last 30 years, given that it is an inexpensive, time-efficient, and non-invasive method to monitor the status of cardiovascular fitness (Achten & Jeukendrup, 2003; Buchheit, 2014). In spite of the large amount of scientific research and practical applications, monitoring training responses to sport using HR measures is not widely implemented (Buchheit, 2014). In particular in the case of TOW, to the best of the author's knowledge, few data have been published about resting HR, which was 64.3 (1.6) beats/min and slightly below the average of 65–67 beats/min for sedentary men of the same age group. Besides, maximum HR (190.8 (2.5) beats/min) was within the expected range of 186–203 beats/min (Warrington, Ryan, Murray & DuVy, 2001).

The maximal oxygen uptake (VO_{2max}) has tended to be related to the performance attained by athletes in different sports (Hagberg, Moore, FerrellHagberg, Moore & Ferrell, 2001) and may be a good predictor of performance (Lucia, Hoyos, Pérez, Santalla & Chicharro, 2002). Although there is no measurement of the VO_{2max} of pullers during competition (probably due to technical and regulatory difficulties), Warrington et al. carried out research in the course of which they measured of pullers' VO_{2max} in a treadmill running test, obtaining a mean value of 55 ± 1.6 ml/kg/min. This value is lower than those recorded in athletes in endurance sports but higher than those recorded in some athletes in team sports such as rugby players (Warrington et al., 2001).

Finally, the 10-point scale used is the modified Borg scale perception effort (RPE) (Borg, 1982), which has historically been used to assess perceived exertion of the athlete during the activity, and which provides a magnitude of the effort being made according to their psychological perception and with which we can compare those values to physiological ones. Despite its long history, there is a paucity of information on the physiological characteristics of TOW to the best of the author's knowledge. Measurements of physiological parameters are key to understanding the demands of an activity, and to identifying limiting factors. Therefore, the main aim of this study was to evaluate the intensity and effort demand required by TOW pullers during competition at the Nations European Championship.

Methods

Participants

Data were collected from 7 male pullers (Height: 175.14 ± 4.85 ; body mass: 77.39 ± 3.92 ; Age: 39.86 ± 11.68 ; %Fat: 17.56 ± 5.21 ; VO_{2max} : 44.24 ± 8.38) in the 560 kg category who were assessed during the Nations European Championship and the following week (Table 1). All of them were international pullers. Before the study, all participants underwent a physical examination by the team physician and each was cleared of any medication or endocrine disorders that might either confound or limit their ability to participate fully in this research. None of them had a previous history of injury, disease or was taking medication during the study, and they participated voluntarily, giving written informed consent. The study was designed in compliance with the recommendations for clinical research set out in the Declaration of Helsinki of the World Medical

Association (2008), updated in Fortaleza (WMAD, 2013). The protocol was reviewed and approved by the ethics committee for the University of Deusto (M10_2017_108).

Table 1
Descriptive Characteristics of the pullers

	n=7
	Mean \pm SD (min-máx.)
Age (years)	39.86 \pm 11.68 (22-59)
Height (cm)	175.14 \pm 4.85 (167.5-180.5)
Body Mass (Kg)	77.39 \pm 3.92 (72.7-81.9)
Body Fat (%)	17.56 \pm 5.21 (9.40-24.50)
VO _{2max} (mL·min ⁻¹ ·kg ⁻¹)	44.24 \pm 8.38 (28-52.60)

Procedure

Data were collected during the Nations European Championship and the following week's competition phase (peak of fitness) on 9 September 2019 (2 macrocycle periods), after the athletes had completed 40 weeks' practice. The pullers trained on average 12 hours per week, and participated in 6 tournaments during the regular season, with duration of pulls and rest times between them being recorded. The LAC were assessed before and after the end of each match, and the global RPE at the end of the matches was recorded with 11 matches in total being measured. The following week, pullers performed a graded exercise test (GXT) on a treadmill (Medisoft Model 870S). All dependent variables were assessed before, during and at the end of the GXT to calculate the individual anaerobic threshold. Before starting the exercise test, participants warmed up for 5 minutes at 65% of their maximum HR by running on a treadmill and, after a 3–4-minute started the incremental test. After the warm-up, they began the test at 7km/h and a 1.5 incline, performing actively for 3min and with 1min rest between active blocks. The speed was increased by 1km/h between blocks, with participants running the test until reaching volitional fatigue. At the end of each block, HR, LAC, VO_{2max} and RPE were recorded. All participants were voluntarily able to halt the assessment process at any time, and at the end of the test, participants were allowed an active recovery period of 5 minutes' duration on the treadmill. (Benito-Peinado et al., 2005; Faude & Kindermann, 2009)

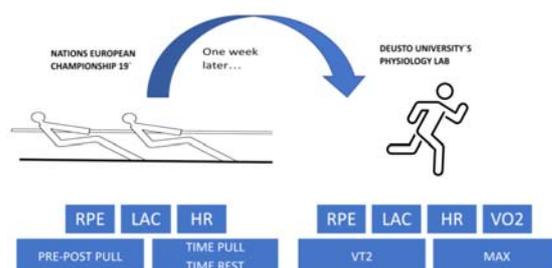


Figure 1: Figure showing the protocol used

Anthropometric measurements

All measurements were taken by the same technician, who was trained and deemed to be competent by an ISAK-Level 2 anthropometrist in accordance with The International Society of Advancement of Kinanthropometry (ISAK) protocol (Lee, Wang, Heo, Ross & Janssen, 2000). Three series of anthropometric measurements were taken for each site and the mean was recorded. Height (cm) was measured using a SECA[®] stadiometer to 1-mm accuracy, while BM (kg) was measured using a SECA[®] scale to a precision of 0.1 kg. BMI was calculated using the BM/height² (kg/m²) formula, and a Harpenden[®] skinfold calliper to 0.2 mm precision was used to measure the triceps, abdominal, suprailiac, front thigh, subscapular and peroneal skinfolds. For its part, a Lufkin[®] metallic woven tape to 1 mm precision was used to measure the perimeters (relaxed arm, thigh and peroneal) in cm, with bone diameters (wrist and femur, cm) being measured using a Holtain[®] bicondylar calliper to 0.1 cm precision. To calculate FM, MM and bone mass, we used the Carter (Carter, 1990); Lee et al. (Lee, Wang, Heo, Ross & Janssen, 2000) and Rocha (Rocha, 1975) equations, respectively. Lastly, the somatotype components were processed using the Carter and Heath formula (Mielgo-Ayuso, Urdampilleta & Martinez-Sanz, 2012).

Physiological measurements

Heart rate

A Polar HR monitor and A transmitter (Polar Electro, Lake Success, NY, USA) (Goodie & Larkin, 2000) was used to measure HR, which was recorded during the incremental test protocol (Boudreaux et al., 2018; Goodie, & Larkin, 2000).

Blood Lactate concentration

The LAC was assessed using a Lactate Scout 2 (Bonaventura, Sharpe, Knight, Fuller & Tanner, 2015; Tanner & Fuller, 2010) handheld blood lactate analyser (SensLab GmbH, Leipzig, Germany), while BLA measurements were taken from blood extracted from a finger, with the first drop always being discarded to avoid contamination.

RPE

In sports and particularly exercise testing, the RPE, as measured by the 10-point modified Borg scale (Borg, 1982) is a frequently used quantitative measurement of

perceived exertion during physical activity.

Oxygen consumption

To perform the incremental test, VASA ergometer test (Vasa, Inc., Essex Junction, VT, USA) was used to assess the VO_2 and expired gases were collected and analysed using a calibrated continuous breath-by-breath gas exchange and ventilation measurements at the mouth (Ergostik, Geratherm Respiratory GmbH, B Kissingen, Germany). The metabolic cart was calibrated to manufacturer recommendations before every test.

Statistical analysis

The results are expressed as mean \pm standard deviations, frequencies and percentages, after determining normal parameters using the Shapiro-Wilk test (<50). Correlations between lactate concentrations and RPE values were reported by the Spearman correlation, with the magnitude of the correlation coefficients being determined as trivial ($r < 0.1$), small ($0.1 < r < 0.3$), moderate ($0.3 < r < 0.5$), high ($0.5 < r < 0.7$), very high ($0.7 < r < 0.9$), nearly perfect ($r > 0.9$), or perfect ($r = 1$) (Hopkins, Marshall, Batterham, 2009). For its part, statistical analysis was performed using the statistical software package SPSS[®] Version 27.0. (SPSS, Inc., Chicago, IL, USA), with differences being considered statistically significant in cases where $P < 0.05$.

Results

A total of 23 pulls were recorded against 11 opposing teams: 2 pulls with each team and 3 pulls against one team (there was one null pull). The average duration of the pulls was 228.45 ± 129.95 sec, which shows the great variability of their duration in this activity, with the longest pull being 15 minutes and the shortest 22 seconds. Similarly, there was great variability in terms of the rests between pulls, insofar as the rests between matches and among teams was 963.7 ± 506.36 sec, while those between pulls with the same team was 151.00 ± 29.23 sec - all of which were close to 2 minutes (Table 2).

Table 2
Average duration in seconds in pulls and breaks.

	Mean \pm SD	min	Max
Rest between pulls against the same team	151.00 \pm 29.23	95	203
Time pulling	228.45 \pm 129.95	38	420
Breaks between matches with different teams	963.70 \pm 506.36	422	2152

In terms of the physiological variables, the average HR recorded in the treadmill tests was 175 ± 14 beats

per minute. However, due to the difference between those participants who obtained the highest threshold HR value (Participant number 6 with 193 beats) and those with the lowest threshold HR (Participants 2 and 4 with 158 beats), namely, a difference of 35 beats, it is difficult to generalise about this value (Table 3).

Table 3
Values recorded during the pulls and during the incremental treadmill test

	1	2	3	4	5	6	7	total
Lac pre match	5.1 \pm 2	4.9 \pm 1.6	5.3 \pm 2.4	4.3 \pm 1.5	4.3 \pm 1.4	5.5 \pm 2.2	4.5 \pm 1.5	4.8 \pm 1.8
Lac post match	6.2 \pm 1.8	5.9 \pm 2	7.3 \pm 2.8	4.9 \pm 1.1	5 \pm 1.1	7.1 \pm 2.2	5.8 \pm 1.4	6 \pm 1.8
RPE post match	6.1 \pm 1.2	6 \pm 1.3	5.7 \pm 1.6	5.9 \pm 1.6	5.9 \pm 2.2	6 \pm 1.5	6.5 \pm 1.5	6 \pm 1.6
HR Lab VT ₂	169	158	180	158	181	193	188	175 \pm 14
LAC lab VT ₂	4.6	4	4.2	3.7	3.7	5.1	4.3	4.2 \pm 0.5
RPE Lab VT ₂	8	6	7	8	7	8	8	7.4 \pm 0.8
VO ₂ Lab VT ₂	45.4	37.8	42.8	27	44.3	40.1	35.6	39 \pm 6.3

Legend: Lab: laboratory; VT₂: second ventilatory threshold; VO₂ max: Maximum Oxygen uptake
HR: Heart rate; LAC: Blood lactate concentration

The mean **LAC** values recorded at the end of the matches were 6 ± 1.9 mmol/l, 32% higher than the mean values recorded for the individual anaerobic threshold intensity 4.2 ± 0.5 mmol/l recorded in the GXT (a difference of 1.9 mmol/l). Athletes' pre-match LAC values were higher than those recorded for the threshold in the treadmill test (4.8 ± 1.8 Vs 4.2 ± 0.5).

The mean **RPE** values of athletes after the matches (6 ± 1.5 A.U) were 21% lower than the mean RPE values obtained for the intensity of the individual anaerobic threshold 7.6 ± 0.8 A.U in the GXT. With the exception of one puller, all the other pullers reported a higher RPE for the threshold zone in the treadmill test than after the matches (Figure 2).

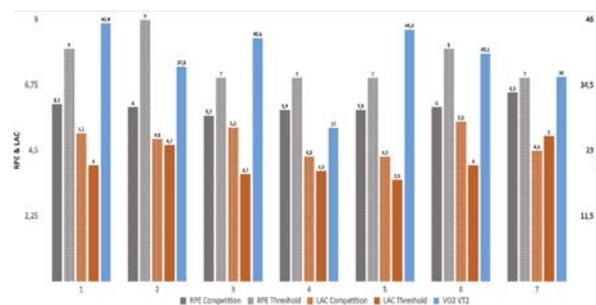


Figure 2: Individual values of RPE and BLA in competition and individual threshold and O_2 consumption.

The mean values recorded for lactate threshold **oxygen consumption** in the treadmill test were 39 ± 6.3 ml/kg/min, although as with HR, they varied greatly among participants, with up to 18.4 ml/kg/min difference between the highest and lowest values.

There were no significant correlations between LAC and RPE recorded at an anaerobic threshold intensity during the incremental test and no statistically significant correlations were observed among the results (4.2 ± 0.5 mmol/l; 7.4 ± 0.8 ; $p > 0.05$).

Discussion

The main aim of the current research was to evaluate the intensity and effort made by athletes during a European championship TOW event on land. The main finding demonstrated how the LAC values of pullers recorded after matches proved to be higher than those recorded in the laboratory running for threshold intensity, although RPE values after the matches were reported to be lower than those at threshold level during an incremental treadmill test.

Based on these results and despite the lower RPE values, the LAC values recorded both after and before the competition matches were higher than LAC obtained for the anaerobic threshold intensity in the incremental test. These data support the idea about the glycolytic demands of this sport and raises doubts related to the strategies used until now (static recovery) for recovery between matches (Bogdanis, Nevill, Lakomy & Graham, 1996; Spierer, Goldsmith, Baran & Hryniewicz, 2004).

Facing new glycolytic stimuli with such high LAC can decrease performance (Carr & Hopkins, 2011), and this is the main reason why it might make sense to apply different strategies to help metabolization of the accumulated lactate as well as a reduction in the accumulated amount, such as bicarbonate supplementation (Hilton, Leach, Hilton & Sparks, 2020; Wu, Shih, Yang & Huang, 2010), beta alanine supplementation (Berti Zanella & Donner Alves, 2017), or active recovery between matches (Bogdanis, Nevill, Lakomy & Graham, 1996; Spierer, Goldsmith, Baran & Hryniewicz, 2004).

On the other hand, the RPE values reported by pullers for threshold intensity in the incremental treadmill test were higher than those reported after the competition matches. This difference between LAC and RPE values reported may be due to the fact that the pullers may be more accustomed to suffering in their respective activities (pulling the rope) than running on a treadmill (Pandolf, 1982) or to the delay in increase in blood lactate concentration after a high intensity stimulus such as that experienced in pulls (Gollnick & Bayly, 1986).

It was difficult to make comparisons with HR and O_2 consumed values due to the lack of competition data. Likewise, due to the nature of the stimuli performed in TOW competitions, which are discontinuous and of high intensity, comparing heart rate values would be subject to great limitations. It is therefore necessary to create a validated protocol to be able to test/evaluate athletes

in a «controlled» situation and thus be able to compare these data with competition values. The only reference that exists on oxygen consumption values in pullers (Warrington, Ryan, Murray & DuVy, 2001) obtains VO_{2max} values from pullers in an incremental treadmill test and compares them with those of rugby players, with the pullers obtaining the best relative values. In our case, VO_{2max} was not obtained given that the aim of the study was to determine the threshold in order to compare data with those obtained in competition. As such, future studies would need to analyse the VO_{2max} during competition using portable technology in order to better understand physiological responses during competition (Winkert, Kirsten, Kamnig & Steinacker, 2021).

Finally, it is important to note the great variability in length of pulls and the length of breaks between matches with different opponents (Warrington, Ryan, Murray & DuVy, 2001). As for the variability of length of pull, this is most likely due to the different conditions in which the ground can be found (very hard with difficulty in securing boots, or very soft making it easy to secure the position), or to opponents' level. The physical demands that may be required for pulls of less than 30sec or pulls of more than 10 minutes are very different and should condition the way the pullers train, whether in a more explosive or more aerobic/oxidative manner (Astrand, 1979).

However, in the case of breaks between matches, this variability may be largely due to the length of the matches, since first there is a group stage and then the semi-finals and final or third and fourth places. Despite part having taken some long breaks during the competition (the longest being almost 36 minutes), the lactate values on entering the shoot did not fall below 2.5 mmol/l in any of the pullers, which demonstrates a poor recovery strategy on the part of the athletes between pulls. This is the case even though they had made a glycolytic effort before stopping and the blood lactate concentration increases after finishing the stimulus (Gollnick & Bayly, 1986), once the maximum peak has been reached at around 5 minutes (Morrow, Fell & Gladden, 1988). Furthermore, taking into account that participants were trained subjects in good physical condition, they should be able to reduce these concentration levels before returning to the competition or consider different strategies with the aim of accelerating recovery (Galaz-Campos, 2020; Mazuera-Quiceno, Dávila-Grisalez, Calderón-González, Palacios-Ruales & Tobar-Gutiérrez, 2021).

Conclusions

The intensity and effort response were found to be higher and kept above the anaerobic threshold during competition in TOW pullers. These data might help coaches better understand the demands of this sport in terms of intensity and effort, as well as highlighting the importance of actions aimed at reducing the concentration of lactate (both related to physical preparation and ergonutritional) among pulls in TOW competitions.

Practical Applications

Having obtained reference values for LAC in competition helps us gain insight into the importance of glycolytic metabolism in this sport and also helps improve the focus and direction of training. Protocols should thus be implemented with the aim of avoiding or reducing the lactate concentrations with which pullers begin to compete.

Future lines of research

Taking into account the difficulty or impossibility of controlling some physiological variables in competition, the design of a validated test in the laboratory could be viewed as a great help in comparing or better understanding the physiological demands of pullers in their competitions. On the other hand, there are still no known physiological reference values in TOW competitions on rubber surfaces or referring to women or larger samples than those measured in this research.

Limitations

There are three major limitations of this study. The first is due to the rules and dynamics of the competition itself, which makes it impossible to take lactate just after completing the activity, with between 50-80sec having to elapse for the pullers to leave the area where the competition takes place.

On the other hand, due to the highly variable durations and rests in the different competitions, it is difficult to suitably define the physiological demands of those athletes.

Finally, the obvious limitations of comparing LAC obtained from different activities is a limitation that is currently difficult to prevent in this sport.

Conflict of Interest Statement

The authors declare that the review was conducted in the absence of any conflict of interest. Our institution did not receive payment or services from any third party for any aspect of the work submitted, and we declared no financial relationships with entities that could be perceived to influence, or that give the appearance of potentially influencing our work.

Author Contributions

Conceptualization, A.C.-B. and A.C.; Data curation, A.C.-B. and B.G.-S.; Formal analysis, A.C.-B., R.C. and J.C.G.; Investigation A.C.-B.; Project administration, A.C.-B. and A.C.; Software, B.G.-S.; Supervision, R.C. and J.C.G.; Writing—Original draft, A.C.-B., B.G.S. and A.C.; Writing—Review & editing, R.C. and J.C.G. All authors have read and agreed to the published version of the manuscript.

Funding

The authors declare no funding sources.

Acknowledgments

The authors wish to express their gratitude to the International Tug of War Federation for facilitating data collection and to all the pullers who participated in the study for their effort and availability.

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