Original Article

doi: 10.16926/par.2022.10.15

Differences in the Force-Velocity profile between Judoist and freestyle wrestlers

Juan Antonio Párraga Montilla [1ABD], Pedro Ángel Latorre Román [1AC], Victor Serrano Huete [2AB], José Carlos Cabrera Linares [1BD], Emilio D. Lozano Aguilera [3BC], Pedro Jiménez Reyes [4ACD]

[1] University of Jaén, Department of Didactic of Corporal Expression, Spain
[2] University Isabel I. Burgos, Department of Physical Education, Spain
[3] University of Jaén, Department of Statistics and Operations Research, Spain
[4] Centre for Sport Studies, Rey Juan Carlos University, Madrid, Spain

Authors' Contribution: A – Study Design, B – Data Collection, C – Statistical Analysis, D – Manuscript Preparation, E – Funds Collection

Abstract

Background: The aim of this study was to gain new knowledge about the force-velocity (F-V) profile in Judoist and freestyle wrestlers, investigating if there were any differences between sports and which physical demands have which fighting modalities. *Participants:* 24 athletes (male) took part in this study. Twelve Judoist (age: 20.3 ± 3.9 years, weight: 76.4 ± 10.4 kg; height: 179.4 ± 5.3 cm; BMI: 32.2 ± 1.9 kg/m^2) and twelve freestyle wrestlers (age: 19.6 ± 4.5 years, weight: 65.3 ± 13.6 kg; height: 177.5 ± 5.7 cm; BMI: 23.8 ± 1.8 kg/m^2) participated. *Methods*: To evaluate the F-V profile, the participants performed a squat jump (SJ) without load, as well as with different load conditions (0, 25, 50, 75, and 100% of athlete's body mass). To assess the height of the jump, the OptoGait system was used. Consequently, the theoretical maximal force (F_0); the theoretical maximal velocity (V_0); maximal mechanical power output (P_{max}); slope of the linear F-V relationship (S*fv*); optimal F-V profile (Sfv_{opt}); and the differences between Sfv and Sfv_{opt} ($FV_{imb\%}$) were obtained. *Results*: A higher F_0 and lower V_0 were found in Judo athletes compared to wrestlers. Significant differences were found in S*fv* and FV_{imb} ($p<0.001$). *Conclusion:* The F-V profile is an accurate, reliable, and economical method that facilitates the evaluation of the current state of the athlete individually. *Practical applications*: The F-V profile method allows coaches and athletes to adjust their training objectives to achieve a higher level in their sport.

Keywords: Force-velocity profile, Judo, wrestling, and Squat Jump.

Address for correspondence: José Carlos Cabrera Linares - email: jccabrer@ujaen.es

Recevied: 17.11.2021; Accepted: 2.02.2022; Published online: 9.02.2022

Cite this article as: Párraga Montilla, JA, Latorre Román, PA, Serrano Huete, V, Cabrera Linares, JC, Lozano Aguilera, E, Jiménez Reyes P.Differences in the Force-Velocity profile between Judoist and freestyle wrestlers. Phys Act Rev 2022; 10(1): 141-149. doi: 10.16926/par.2022.10.15

INTRODUCTION

Combat sports are characterised by intermittent actions which are performed with high intensity [1, 2]. Achieving the appropriate intensity requires complex skills to achieve maximum performance, as well as the optimisation of force capacity [3]. Judo and wrestling can be considered adversary sports. Specifically, Judo is a fight sport in which the athletes use control techniques over the neck or elbow in order to win in combat. Among others, a Judo victory depends on physical strength, technique, tactic, strategic, and physiological variables [4, 5] due to the intermittent character of this sport [6, 7]. For that reason, Judoists need to have high technical and tactical levels [8], in addition to a high level of force capacity and endurance to control and destabilise the opponent [9]. Furthermore, it needs high muscle power for the execution of projection techniques [10]. Consequently, Judo is a high-intensity sport that requires an elevated force capacity, specifically, the isometric force for the use of the projection techniques in fights depending on grips [11].

Judo fights last five minutes in real-time. However, combat may end early if any of the Judoists receive an ippon (maximum score). In a high-level championship, a Judoist has to complete between five and seven matches in order to qualify for a medal [10]. By contrast, freestyle wrestling has three periods of duration (two minutes each) with thirty seconds of rest between periods. High-intensity actions are decisive in combat sports performance, meaning that the application of the greatest force in a velocity regime is important.

Traditionally, the method used to assess the maximum force that an athlete can apply against a certain load or in a sporting action has been the maximum repetition method (1RM) [12]. Despite its prolonged use, the 1RM method presents a high risk of injury for athletes due to the high physical demand that it requires. In addition, another limitation is the time that is needed to assess a large group of athletes [13]. According to novel perspectives in training and quantification of the athlete's force, a new testing methodology based on the force-velocity (F-V) relationship has recently emerged with the expectation of providing more meaningful data to implement individualised training programmes [14]. Namely, the force and velocity data collected during vertical jumps performed against two or more loads can be used to model a linear F-V relationship [15].

The four main variables obtained from the linear F-V relationship are the theoretical maximal force (F_0), the theoretical maximal velocity (V_0), the slope of the F-V relationship (*Sfv*), and the theoretical maximal power (P_{max}). Therefore, F_0, V_0, and P_{max} represent the external mechanical limits of the entire neuromuscular system to produce force, velocity, and power, respectively [16]. These three parameters are commonly identified as the maximal mechanical capacities of the lower limbs when obtained from the jumping testing procedure. However, no previous studies have examined whether the F-V profile could identify each individual combat discipline characteristic according to F-V parameters. This manifestation allows individual level examinations, facilitating greater improvements in athlete performances regardless of their physical level [17].

The F-V relationship has been assessed through different protocols such as accelerometery, linear position transducer, and Samozino's methods. Giroux et al. [18] concluded that the Samozino's method provides the greatest reliability. Consequently, it is vital to mention the importance of power in this sport modality, as well as the relationship between force and velocity to achieve maximal power (P_{max}). Power can be defined as the amount of work done in the unit of time or as the product of force and velocity [19]. Both force and velocity are influenced by the intrinsic properties of muscle, such as length-tension and F-V relationships [20]. At this point, it is important to noticed that the same P_{max} can be achieved from different combinations of F_0 and V_0 [14]. Interestingly, the literature has shown that there exists an optimal combination of F_0 and V_0 (i.e., *Sfv*) that allows the maximisation of ballistic performance for the same value of P_{max} [16]. Consequently, specific training programmes can be prescribed to reduce the imbalance between force and velocity (i.e., FV_{imb}) [21]. However, it is unknown whether the *Sfv* (i.e., if athletes with a force-oriented or velocity-oriented profile) could achieve better physical performance in different combat sports.

Therefore, the aim of this study was to gain new knowledge about the F-V profile in Judo and freestyle wrestling. A secondary aim was to identify the physical demands of each of these fighting modalities.

Our initial hypothesis is that there were differences in the F-V profile between the modalities of both sports. Specifically, Judoists will have an F-V profile designed for force when compared with wrestlers, since a greater force level is needed in Judo.

MATERIAL AND METHODS

Participants

24 athletes (males), specifically 12 Judoists and 12 freestyle wrestlers, participated in this study. Anthropometric characteristics of the participants are listed in Table 1. Because the Judoists and wrestlers belonged to the same club, the weekly training schedule was similar. Hence, participants (Judoist and wrestler) trained at least three sessions per week in technical-tactic performance (TT) (1.5 hours each session), and three sessions of conditioning training (CT) (1, 1.25, and 1.25 hours, respectively), with one day of total recovery among sessions. Subsequently, the total training hours were similar for each sport modality (i.e., 4.5 hour/week for TT, and 3.5 hour/week for CT). The main training differences between groups were the specific tasks in each sport modality. Thus, the training programmes were adjusted by the coach in relation to the specific requirements of each sport.

To participate in this study, participants must have not had any injury that prevented them from attending the training sessions for more than a week in the six months prior to starting the evaluations. Before being recruited to the study, participants read and signed the informed consent form, and the clubs gave their written authorisation. This study was approved by the bioethics committee of the University of Jaén, Spain (Ref.: MAR.17/1). In addition, all experimental procedures have been designed following the ethical recommendations approved in the Declaration of Helsinki (2013).

In addition, participants had a high physical level in their specialty (approximately 90-95% of its peak sport form) since the assessment's session was conducted two weeks before the most important season competition. Furthermore, all athletes were competing at the national level (participants and/or medallists in a Spanish championship and some of them medallists in an international championship) when we assessed them. Table 2 contains the participants' training experience, the competitive level, and the best results obtained at the moment of assessment.

Table 1. Anthropometric characteristics of the participants.

Indicator	Total Mean ± SD	Judo Mean ± SD	Wrestling Mean ± SD
Number	24	12	12
Age (years)	19.75 ± 4.2	20.3 ± 3.9	19.6 ± 4.5
Height (cm)	178.45± 5.5	179.4 ± 5,3	177.5 ± 5.7
Weight (kg)	70.67 ± 11.82	76.04 ± 10.04	65.3 ± 13.6
BMI (kg/m^2)	28 ± 1.85	32.2 ± 1.9	23.8 ± 1.8

SD - standard deviation; BMI - Body Mass Index

Table 2. Training experience, competitive level, and the best results of the participants

Sport	Competitive level	Total N=24	Training experience (years)			Competitive Experience (years)			Best place			
			5-10	10-15	+15	5-10	10-15	+15	1st	2nd	3rd	4nd
Judo	Spanish Championship	N=12	N=1	N=4	N=7	N=5	N=6	N=1	N=1	N=4	N=4	N=3
Wrestlers	Spanish Championship	N=8	-	N=5	N=3	N=1	N=5	N=2	N=8	-	-	-
	European Championship	N=4	N=1	N=2	N=1	N=1	N=3	-	-	N=3	N=1	-

Materials

The height (cm) of the participants was measured with a portable stadiometer (Seca 222, Hamburg, Germany). A scale was used for body weight (kg) (Seca 899, Hamburg, Germany). Moreover, participants' body mass index (BMI) was calculated by applying the formula weight (kg)/height^2 (m). Anthropometric analysis was complete following the requirements of Samozino's method. This protocol measured the vertical distance between the floor and the greater trochanter of the right leg at a squat position with a knee angle of 90°, as well as the distance from the hip to the top of the foot supine (Lufkin W606PM, Marylan. USA).

Mechanical variables

Squat Jump (SJ): To measure SJ, an OptoGait (Microgate, Bolzano, Italy) device was used. OptoGait is an optical data acquisition system composed of a transmitter and a receiver bar. Each 1-m bar contains 96 infrared LEDs (1041 cm resolution) and is located on the transmitter bar; these are continuously communicating with the LEDs located on the receiver bar. The bars measure flight and contact times during execution with an accuracy of 1/1000 of a second. This device has been used in previous studies [2, 18, 23].

SJ (loaded condition): To perform the SJ in loaded conditions, an Olympic barbel was used (Salter, Spain). Furthermore, extra weight was added (2.5 kg and 5 kg) to complete the loaded conditions (i.e., 25, 50, 75, and 100% of body mass).

Theoretical maximal force (F_0): F_0 was assessed considering the maximal concentric force value that athletes' lower limbs could theoretically produce (per unit body mass) during a ballistic push-off (N/Kg).

Theoretical maximal velocity (V_0): V_0 was considered as the theoretical maximal extension velocity of the lower limbs during ballistic push-off (m/s).

Maximal Power (P_{max}): This dictated the maximal power output capability of the athlete's lower-limb neuromuscular system (per unit body mass) in the concentric and ballistic extension motion (w/kg).

Slope of the linear F-V relationship (Sfv)*:* Index of the athlete's balance between force and velocity capabilities*.* The steeper the slope, the more negative its value, the more "force- oriented" the F-V profile, and vice versa.

Optimal F-V profile (Sfv_{opt}): This represents the optimal balance between force and velocity capabilities for a given individual. A training programme should be developed to orient Sfv *to* $Sfv_{opt.}$ This will allow participants to maximise jump height.

Force-velocity imbalance (FV_{imb})*: Calculated as* the magnitude of the difference between the Sfv and optimal F-V profiles (Sfv_{opt}) for a given individual. A value of 100% means $Sfv = Sfv_{opt}$ (i.e., optimised F-V profile). A value above 100% means there is an imbalance with a deficit in velocity, and vice versa.

Procedures

We evaluated the F-V profile with the protocol defined and validated by Samozino et al. [22]. To determine P_{max}, F-V profile, and FV_{imb}, each participant performed an SJ or jump without countermovement. To perform it properly, the athlete had to leave a static position with their arms locked and the flexion of their legs at 90º; all the movement is performed in an upward direction [16, 24]. The participants executed two repetitions of the defined loaded and unloaded conditions. The best jump was selected for analysis, and two minutes rest was established between repetitions [16]. Participants were not allowed to do physical activity 72 hours before the session.

Before data collection, participants did a 10-minute standard warm-up (five minutes of general exercises and five minutes of specific lower limb exercises). During the execution of the SJ jumps (with and without loads), the participants were verbally encouraged to reach the maximum vertical height in the jump. Before performing the SJ, sufficient supervised practice was allowed to automate the movement in order to be executed with jumps flexion and without countermovement. All subjects were able to perform the SJ with adequate execution as they had already automated the technical action during their training.

The athletes completed five different jumps in different load conditions (i.e., 0, 25, 50, 75, and 100% of their body mass). For unloaded conditions, they placed their hands on their hips; no machines with guides or similar devices were used. For loaded conditions, participants kept their hands on the bar. In addition, they were instructed to maintain an upright chest position so that the weight of the loaded bar was directed vertically towards the ground. SJs started with a downward movement until an angle of 90° (knees in an initial flexed position) was reached, measured in advance as the vertical distance between the ground and the greater trochanter of the right leg and checked by the researcher using a vertical ruler before the test. After maintaining this position for at least two seconds, they were asked to apply maximum force as quickly as possible by jumping to their maximum height, keeping their hand on their hips and their feet stretched out when the jump was performed. To avoid counter-movements, verbal indications were given to ensure proper execution. If these requirements were not met, the test was repeated [17].

Statistical Analysis

The data analysis was performed with SPSS software, v.19.0 for Windows (SPSS Inc, Chicago, USA). The significance level was set at $p<0.05$. Descriptive statistics are presented as mean and standard deviation (SD). The normality of the distribution and the homogeneity of the sample were checked with the Kolmogorov-Smirnov and Levene's test. An analysis of covariance (ANOVA) was performed to verify the differences between groups. We conducted Cohen's d test to identify the effect size (ES). The criteria for interpreting the magnitude of the ES were 0.2 small, 0.5 medium, and 0.8 large [25].

RESULTS

Table 3 represents the F-V profile variables analysed as means and SD. Significant differences ($p<0.001$) between Judoist and freestyle wrestlers were found in F_0, V_0, S*fv*, and F-V_{imb}, as well as in P_{max} ($p<0.05$). Regarding Cohen's d, a large ES was found in F_0, V_0, S*fv*, P_{max}, and F-V_{imb} variables, whereas a trivial ES was shown in SJ.

Figures 1 and 2 reveal the regression analysis with the calculation of the F-V profile determined by the SJ in each of the variables analysed.

A comparison between Judo and freestyle wrestling athletes in the F-V profile is illustrated in Figure 3. On the one hand, Judoists presented a deeper F-V relationship, which implies an F-V profile skewed towards force over velocity. On the other hand, freestyle wrestlers showed an F-V profile with a major orientation to velocity over force.

Table 3. Force – Velocity profile variables.

F-v Profile Variables	Judo Mean ± SD	Wrestling Mean ± SD	p-value	Cohen's d
F_0 (N/kg)	35.7 ± 5.1	26.3 ± 2.1	<0.001	2.517
V_0 (m/s)	2.74 ± 0.44	4.42 ± 1.08	<0.001	2.127
P_{max} (W/kg)	24.14 ± 3.46	28.94 ± 7.26	0.05	0.881
S*fv* ($N \cdot s \cdot m^{-1} \cdot kg^{-1}$)	13.51 ± 3.63	6.34 ± 1.94	<0.001	2.573
F-V_{imb} (%)	95.75 ± 25.80	43.22 ± 12.11	<0.001	2.722
SJ (m)	0.342 ± 0.05	0.332 ± 0.07	0.7	0.171

Significant differences $p<0.05$; F_0 - the theoretical maximal force; V_0 - the theoretical maximal velocity; P_{max} - maximal mechanical power output; S*fv* - slope of the linear F-V relationship; Sfv_{opt} - optimal F-V profile; FV_{imb} % - the differences between S*fv* and Sfv_{opt}; SJ - Squat Jump.

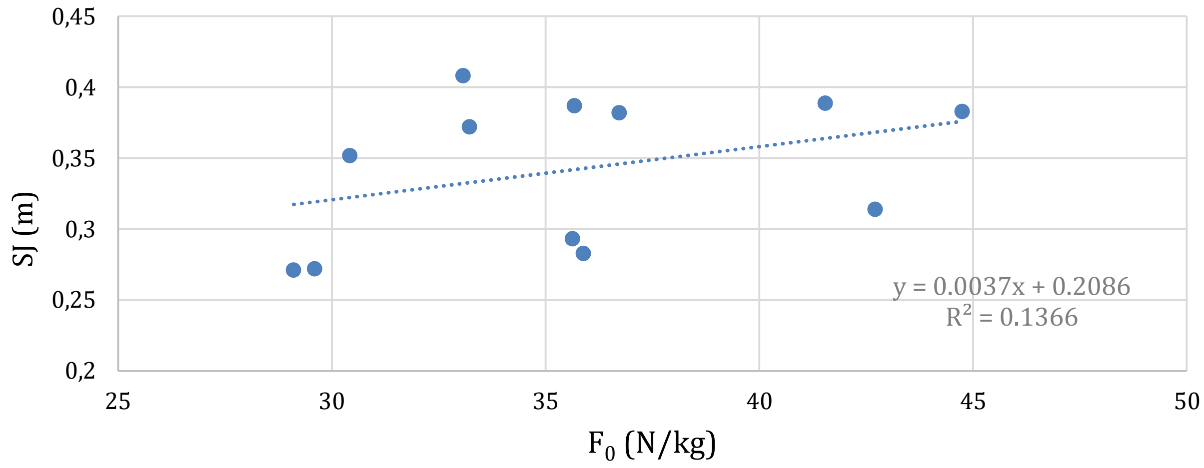

Figure 1. Regression analysis results in Squat Jump Judo (F_0).

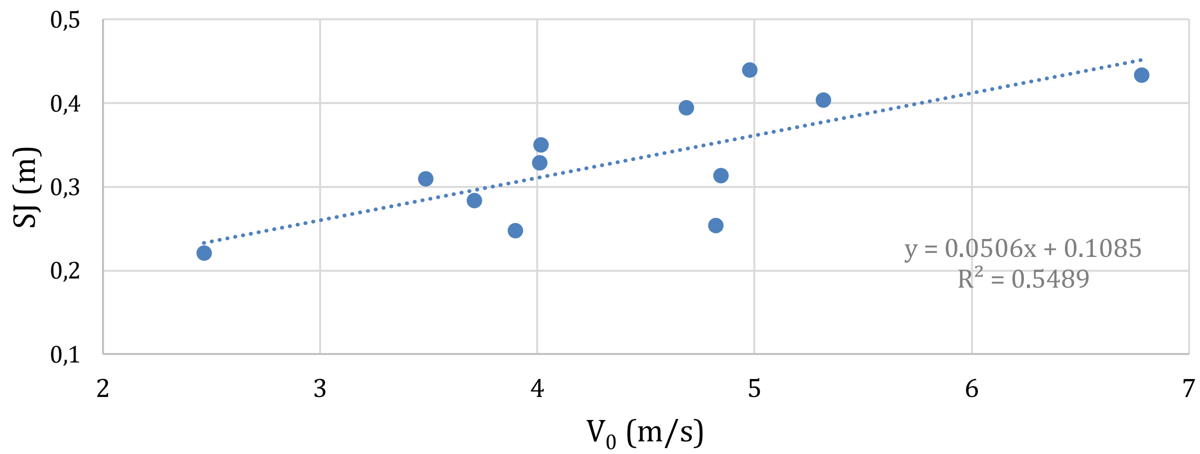

Figure 2. Regression analysis results in Squad Jump wrestling (V_0)

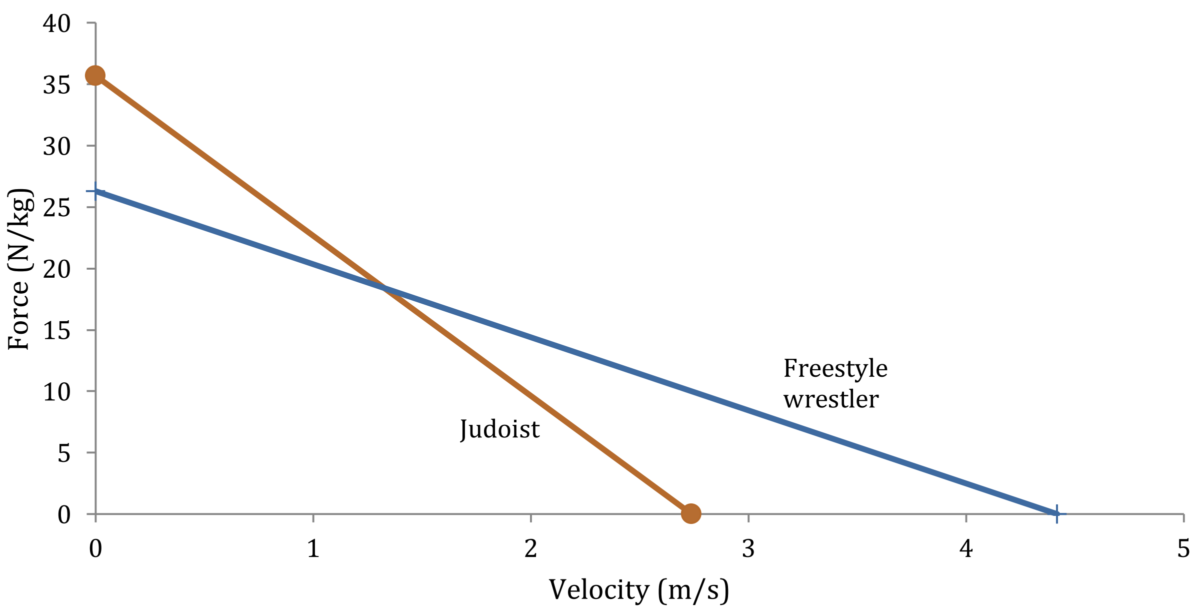

Figure 3. Global comparison between Judo and freestyle wrestling F-V profile.

DISCUSSION

The main aim of this study was to expand the information regarding F-V profiles in Judo and freestyle wrestling. A secondary aim was to identify the physical demands of each sport modality. We calculated F_0, V_0, P_{max}, S*fv*, and FV_{imb} variables. These allowed us to verify the current state of the athlete and to focus training on an individual basis depending on the sport modality, as well as to reduce the FV_{imb}. In this way, the athlete can achieve their greatest potential within their competitive level [26]. Our results showed that significant differences exist in the F-V profile between the sports analysed. This leads us to think that greater force is applied in Judo than in wrestling. Accordingly, our initial hypothesis has been corroborated.

Our results match those obtained in previous studies in high-level Judoist (national and international level) [9, 10] wrestling. These results are also in concordance with those that analysed the physiological requirements of freestyle wrestlers [27]. An explanation for the greater application of force in Judo is due to the importance attributed to the maximum isometric and dynamic strength needed during combat, both (isometric and dynamic) being necessary to achieve victory. This greater application of force in Judo is due to the need to dominate and destabilise the opponent during combat [10]. In the same way, the projections that are made in Judo require greater force and velocity in the lower and upper limbs, which are related to the muscular power that Judoists are capable of developing [28]. Another explanation for these differences can be the explosive attacks and counterattacks that are needed in freestyle wrestling to powerfully lift opponents [29]. These requirements can be seen in our results, since wrestlers showed higher maximum power values than the Judoists. Furthermore, wrestlers' cervical muscle zones seem to be one of the most critical factors for success in a match. Consequently, the differences between grip position (i.e., Judoist grip versus cervical muscle grip in wrestlers) could have an influence in the F-V profile since it requires different utilisations of dynamic, isometric, and explosive strength [27].

We assessed 12 athletes from each sport modality (Judo and freestyle wrestling) at the national level, which is a strength of our study. Consequently, our findings can be generalised to the competitive national level. The F-V profiles obtained in both sports allow us to ascertain the force demands in both disciplines. To the best of our knowledge, the same variables have been analysed in Judo [30] but never in freestyle wrestling. Jiménez Reyes et al. [30] analysed 20 professional-level Judoists (10 men and 10 women), among other athletes, in their study. They evaluated the variables (F_0, V_0, and P_{max}), as well as their correlation and the athletes' performance when executing an SJ and a 20m sprint. The results obtained can be used as a reference to estimate the F_0, V_0, and P_{max} that high-level Judoists need to achieve to compete at this level. However, despite the relationship that may exist between the two tests analysed in this study (i.e., SJ and sprint), and the capacity of predictions according to athletes' performance, F_0, V_0, and P_{max} require further study when the athlete performs the movement to reach a greater transfer to their sport (e.g., SJ in Judo).

Although freestyle wrestling has many practitioners, the variables analysed in this research have not been previously studied in this sport discipline. Therefore, we cannot compare our results with other athletes of this sport modality. Nevertheless, if we compare both sport disciplines, our results show that F_0 were higher in Judoists than in wrestlers. On the contrary, V_0 values were higher in freestyle wrestling than Judo. Hence, in Judo there is a greater force than in freestyle wrestling which implies that the velocity of the execution of the movements is lower in Judo.

Limitations

One of the limitations of our study is that the athletes selected belong to the same sports club. This implies that the training methodology commonly used by athletes has similar characteristics, reducing the distances between disciplines. Consequently, we consider that it is necessary to evaluate and compare these variables in athletes belonging to other clubs in order to establish possible similarities and/or differences between the F-V profile, as well as the F-V imbalances that both Judoist and freestyle wrestlers could have.

A strength of our study was that our participants were top-level athletes. However, we consider it necessary to evaluate the same variables described in this study in Judoist and freestyle wrestlers at a lower competitive level. Similarly, it is necessary to analyse and compare the physiological demands of the female gender through these same variables. This allows coaches to focus on specific aspects that have to be improved in an individualised way, regardless of the competitive category and/or gender of the athlete.

CONCLUSION

To sum, there are differences in Judo's force profile compared with the freestyle wrestling profile. In Judo more force is applied but with less velocity than in freestyle wrestling. Nonetheless, freestyle wrestling has faster and more explosive movements. Hence, a specific training method in Judo and freestyle wrestling disciplines based on the F-V profile should be used, given that it has been demonstrated that an individual training programme focused on F-V imbalance has greater effectiveness compared with a traditional resistance programme [21, 26].

Practical Application

From a practical point of view, this method allows coaches and athletes to identify the current state of their athlete's physical condition in a simple, economical, and effective way. At the same time, it offers the possibility of continuous monitoring of athletes' adaptation to the training throughout the season or during a specific time period. It also means the training objectives can be adjusted according to the F-V deficit. In this way, we can focus on the improvement of force, velocity, or the relationship that exists between them, which allows the athlete to raise their sports level.

ACKNOWLEDGMENTS

The authors are grateful for the participants' selfless commitment and participation in this study.

REFERENCES

1. Bonitch-Góngora JG, Bonitch-Domínguez JG, Padial P, Feriche B. The effect of lactate concentration on the handgrip strength during judo bouts. J Strength Cond Res. 2012; 26(7): 1863–1871. doi: 10.1519/JSC.0b013e318238ebac
2. Serrano-Huete V, Latorre-Román PA, García-Pinillos F, Morcillo Losa JA, Moreno-Del Castillo R, Párraga-Montilla JA. Acute Effect of A Judo Contest on Muscular Performance Parameters And Physiological Response. Int J Kinesiol Sport Sci. 2016; 4(3): 24–31. doi:10.7575/aiac.ijkss.v.4n.3p.24
3. Wąsik J, Shan G. Target effect on the kinematics of Taekwondo Roundhouse Kick - Is the presence of a physical target a stimulus, influencing muscle-power generation? Acta Bioeng Biomech. 2015; 17(4): 115–120. doi: 10.5277/ABB-00229-2014-02
4. Franchini E, Del Vecchio FB, Matsushigue KA, Artioli GG. Physiological profiles of elite judo athletes. Sport Med. 2011; 41(2): 147–66. doi: 10.2165/11538580-000000000-00000
5. Carballeira Fernández E, Iglesias E. Efectos agudos del enfrentamiento en judo: análisis multiparamétrico. Eur J Hum Mov. 2007; 19(0): 117–144. Available from: https://dialnet.unirioja.es /servlet/articulo?codigo=3322978
6. Detanico D, Dal Pupo J, Franchini E, Giovana dos Santos S. Relationship of aerobic and neuromuscular indexes with specific actions in judo. Sci Sport. 2012; 27(1): 16–22. doi: 10.1016/j.scispo.2011.01.010
7. Maamer Slimani, Davis P, Franchini E, Moalla W. Rating of Perceived Exertion for Quantification of Training and Combat Loads During Combat Sport-Specific Activities: A Short Review. J Strength Cond Res. 2017; 31(10): 2889–2902. doi: 10.1519/JSC.0000000000002047
8. Franchini E, Sterkowicz S, Meira CM, Gomes FRF, Tani G. Technical variation in a sample of high level judo players. 2008; 106(3): 859–69. doi: doi.org/10.2466/pms.106.3.859-869
9. Franchini E, Miarka B, Matheus L, del Vecchio FB. Endurance in judogi grip strength tests: Comparison between elite and non-elite judo players. Arch Budo. 2011; 7(1): 1–4.
10. Detanico D, Pupo JD, Franchini E, Dos Santos SG. Effects of Successive Judo Matches on Fatigue and Muscle Damage Markers. J Strength Cond Res. 2015; 29(4): 1010–1016. doi: 10.1519/JSC .0000000000000746

11. Kraemer WJ, Fry AC, Rubin MR, Triplett-Mcbride T, Gordon SE, Perry Koziris L, Lynch JM, Volek JS, Meuffels DE, Newton RU, Fleck SJ. Physiological and performance responses to tournament wrestling. Med Sci Sports Exerc. 2001; 33(8): 1367–1378. doi: 10.1097/00005768-200108000-00019
12. García-Ramos A, Barboza-González P, Ulloa-Díaz D, Rodriguez-Perea A, Martinez-Garcia D, Guede-Rojas F, Hinojosa-Riveros H, Chirosa Ríos LJ, Cuevas-Aburto J, Janicijevic D, Wakley J. Reliability and validity of different methods of estimating the one-repetition maximum during the free-weight prone bench pull exercise. J Sports Sci. 2019; 37(19): 2205–12. doi: 10.1080/02640414.2019.1626071
13. McBurnie AJ, Allen KP, Garry M, Martin M, Thomas D, Jones PA, Comfort P, McMahon JJ. The Benefits and Limitations of Predicting One Repetition Maximum Using the Load-Velocity Relationship. J Strength Cond Res. 2019; 41(6): 28–40. doi: 10.1519/SSC.0000000000000496
14. Morin JB, Samozino P. Interpreting power-force-velocity profiles for individualized and specific training. Int J Sports Physiol Perform. 2016; 11(2): 267–72. doi: 10.1123/ijspp.2015-0638
15. García-Ramos A, Feriche B, Pérez-Castilla A, Padial P, Jaric S. Assessment of leg muscles mechanical capacities: Which jump, loading, and variable type provide the most reliable outcomes? Eur J Sport Sci. 2017;17(6):690–8. doi: 10.1080/17461391.2017.1304999
16. Samozino, Rejc E, Di Prampero PE, Belli A, Morin JB. Optimal force-velocity profile in ballistic movements-Altius: Citius or Fortius? Med Sci Sports Exerc. 2012; 44(2): 313–322. doi: 10.1249/MSS.0b013e31822d757a
17. Jiménez-Reyes P, Samozino P, Cuadrado-Peñafiel V, Conceição F, González-Badillo JJ, Morin JB. Effect of countermovement on power–force–velocity profile. Eur J Appl Physiol. 2014; 114(11): 2281–2288. doi: 10.1007/s00421-014-2947-1
18. Giroux C, Rabita G, Chollet D, Guilhem G. What is the best method for assessing lower limb force-velocity relationship? Int J Sports Med. 2014; 36(2): 143–149. doi: 10.1055/s-0034-1385886
19. Cronin J, Sleivert G. Challenges in understanding the influence of maximal power training on improving athletic performance. Sport Med. 2005;35(3):213–34. doi: 10.2165/00007256-200535030-0000
20. Linnamo V, Moritani T, Nicol C, Komi P V. Motor unit activation patterns during isometric, concentric and eccentric actions at different force levels. J Electromyogr Kinesiol. 2003; 13(1): 93–101. doi: 10.1016/s1050-6411(02)00063-9
21. Jiménez-Reyes, Samozino P, Morin JB. Optimized training for jumping performance using the force-velocity imbalance: Individual adaptation kinetics. PLoS One. 2019; 14(5): 1–20. doi: 10.1371/journal.pone.0216681
22. Samozino, Morin JB, Hintzy F, Belli A. A simple method for measuring force, velocity and power output during squat jump. J Biomech. 2008; 41(14): 2940–5. doi: 10.1016/j.jbiomech.2008.07.028
23. Lehance C, Binet J, Bury T, Croisier JL. Muscular strength, functional performances and injury risk in professional and junior elite soccer players. Scand J Med Sci Sport. 2009; 19(2): 243–251. doi: 10.1111/j.1600-0838.2008.00780.x
24. Samozino P, Morin JB, Hintzy F, Belli A. Jumping ability: A theoretical integrative approach. J Theor Biol. 2010; 264(1): 11–18. doi: 10.1016/j.jtbi.2010.01.021
25. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. Front Psychol. 2013; 4: 1–12. doi:10.3389/fpsyg.2013.00863
26. Jiménez-Reyes P, Samozino P, Brughelli M, Morin JB. Effectiveness of an individualized training based on force-velocity profiling during jumping. Front Physiol. 2017; 1–13. doi:10.3389/fphys.2016.00677
27. Chaabene H, Negra Y, Bouguezzi R, Mkaouer B, Franchini E, Julio U, Hachana Y. Physical and physiological attributes of wrestlers: an update. J Strength Cond Res. 2017; 31(5): 1411-1442. doi: 10.1519/JSC.0000000000001738
28. Campos BT, Cabido CET, Soares YM, Pedrosa GF, Mendes TT, de Almeida RSV. Exercício preparatório de força isométrico aumenta o desempenho de potência muscular de judocas. J Phys Educ. 2018; 29(1): 1–8. doi:10.4025/jphyseduc.v29i1.2910
29. Demirkan E, Koz M, Kutlu M, Favre M. Comparison of physical and physiological profiles in elite and amateur young wrestlers. J Strength Cond Res. 2015; 29(7), 1876-1883. doi: 10.1519/JSC.0000000000000833
30. Jiménez-Reyes, Samozino P, García-Ramos A, Cuadrado-Peñafiel V, Brughelli M, Morin JB. Relationship between vertical and horizontal force-velocity-power profiles in various sports and levels of practice. PeerJ. 2018; 2018(11): 1–18. doi:10.7717/peerj.5937