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Time-motion analysis in freestyle wrestling: Weight category as a factor in different time-motion structures

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Abstract
Background. There is limited knowledge of the time-motion structure of bouts in Freestyle wrestling.
Problem and aim. The main goal of this study was to determine the effort and pause ratios in Freestyle wrestling.
Methods. 297 bouts from the Freestyle wrestling World Championships 2018 were analyzed. Bouts were divided into three weight classes (lightweight, middleweight, heavyweight. For the time-motion analysis, Kinovea software was used.
Results. The effort:pause ratio was determined at 2.4:1. The number of work periods per bout was 8. Most of the bout time was spent in a standing position during the preparation phase. The heavyweight wrestlers spent statistically significant less time in the standing position during the execution time compared to light- and middleweights. The effort and pause ratio for lightweights, middleweights, and heavyweights were determined at 2.2:1, 2.4:1, and 2.5:1, respectively.
Conclusions. The results of our study can be used to prescribe physical training. Future time-motion analyses are needed.

Introduction

According to the official rules [United World Wrestling 2018], a wrestling bout consists of 2 three-minute periods with a 30-second pause. There are three main ways how to win the bout: 1 – victory by „fall" – wrestler is pinned on both shoulders, the bout ends immediately; 2 – victory by technical superiority – wrestler obtains a ten-point lead over his opponent, the bout ends immediately; 3 – victory by points – wrestler obtains at least one point more than his opponent in addition to the two periods if the score is tied the winner is declared by the criteria, the bout ends at the end of the regular time. The criteria for a tie are as follows: 1. the highest value of holds, 2. the least amount of cautions, 3. the last technical point scored [United World Wrestling 2018].

Wrestling is a high-intensity intermittent combat sport that requires complex skills and technical-tactical excellence for success [Yoon 2002; Kruszewski *et al.* 2011; Durech 2012; Chaabene *et al.* 2017]. High-intensity repetitive bouts actions (e.g. attacks and counterattacks) interspersed by low-intensity activities, interruptions, and pauses require both the aerobic and anaerobic coverage [Callan *et al.* 2000; Yoon 2002; Karnicic *et al.* 2009]. The importance of aerobic system is to maintain the recovery process during and between bouts [Callan *et al.* 2000; Gierczuk *et al.* 2012; Chaabene *et al.* 2017]. Previous research of maximal oxygen uptake (VO_{2max}) has shown that level of elite senior male wrestlers VO_{2max} values ranged from 54 to 63 kg/ml/min [Callan *et al.* 2000; Yoon 2002]. Similar values were observed in other combat sports: karate [Chaabene *et al.* 2012], taekwondo [Bridge *et al.* 2014], judo [Franchini *et al.* 2011], amateur boxing [Chaabene *et al.* 2015]. The anaerobic system provides the energy required for short quick bursts of maximal power actions, which represent the significant moments of bout [Hubner-Wozniak *et al.* 2004; Chaabene *et al.* 2017]. Successful wrestlers have shown a high level of anaerobic power and capacity in both upper and lower limbs [Yoon 2002]. Reported anaerobic power and anaerobic capacity for upper limbs ranged

from 7 to 11 W.kg^{-1} and from 4 to 7 W.kg^{-1}, respectively. Reported anaerobic power and anaerobic capacity for lower limbs ranged from 10 to 17 W.kg^{-1} and from 4 to 9 W.kg^{-1}, respectively [Chaabene *et al.* 2017]. The concentration of blood lactate was measured during the 1998 World Championships. The values were 14.8±2.8 mmol/l (range 6.9-20.6) [Nilsson *et al.* 2002].

A detailed description of the activity profile during a wrestling bout has technical-tactical and physiological aspects which can provide important guidelines for coaches [Atkinson, Nevill 2001; Barris, Button 2008; Nevill *et al.* 2008; Drust 2010; Franchini *et al.* 2013; Lopez-Gonzalez, Miarka 2013; Lopez-Gonzalez 2013; Polak *et al.* 2016]. Technical-tactical aspects can simulate the main occurrences during wrestling bouts [Cipriano 1993; Kruszewski *et al.* 2011; Lopez-Gonzalez 2011; Shakhmuradov, Podlivaev 2011; Dokmanac *et al.* 2012; Kruszewski *et al.* 2012; Barkov 2012; Tropin 2013; Boyko *et al.* 2014; Matejova 2016; Miarka 2016; Tunnemann 2016; Arabaci *et al.* 2018] while physiological aspects can help to better understanding of energy system involvement [Nilsson *et al.* 2002; Yoon 2002; Mirzaei *et al.* 2010; Demirkan *et al.* 2012; Chaabene *et al.* 2017].

As it is difficult to conduct physiological measurements during a competition in wrestling, an important way to obtain information for a training prescription is to understand its time structure [Lopez-Gonzalez, Miarka 2013]. The time structure can explain which energy system is dominant, on that basis we can prescribe training programs. Several types of research of time-motion analysis were conducted in combat sports with following the effort and pause ratio, such as judo (ranged from 2:1 to 3:1) [Marcon *et al.* 2010; Miarka *et al.* 2012; Franchini *et al.* 2013; Miarka *et al.* 2014; Dudeniene *et al.* 2017, Julio *et al.* 2018], karate (1:1.5) [Tabben *et al.* 2015], taekwondo (ranged from 1:2 to 1:3) [Tornello *et al.* 2013; Hausen *et al.* 2017], amateur boxing (1:9) [Slimani *et al.* 2017], kickboxing (1:1) [Ouergui *et al.* 2014; Ouergui *et al.* 2019], jiu-jitsu (6:1) [Andreato *et al.* 2013; Andreato *et al.* 2015] and mixed martial arts (ranged from 1:2 to 1:4) [Del Vecchio *et al.* 2011; Miarka *et al.* 2018].

In wrestling, Nilsson *et al.* [2002] conducted a time-motion analysis of the 1998 World Championships in Greco-roman style. The mean duration of a bout was 427 s (range 324-535s), with the effort and pause ratio 3:1 [Nilsson *et al.* 2002]. While Nilsson *et al.* [2002] conducted their research, a wrestling bout lasted 5 minutes with an additional 3 minutes overtime if the score was tied or the difference between the two wrestlers´ scores was less than 3 points.

To the best of our knowledge, no author has yet conducted a time-motion analysis in Freestyle wrestling, furthermore with current rules [United World Wrestling 2018]. Thus the purpose of our study was to: (1) evaluate mean duration of work and pause (effort: pause) ratio in Freestyle wrestling; (2) evaluate mean duration of work and pause (effort: pause) ratio according to weight classes (lightweight, middleweight, heavyweight); (3) evaluate mean duration in activity phases in standing and par-terre position [Lafon 2008] using Lopez-Gonzalez and Miarka´s [2013] classification in Freestyle wrestling; (4) evaluate mean duration in activity phases in standing and par-terre position [Lafon 2008] using Lopez-Gonzalez and Miarka´s [2013] classification according to weight classes.

Methods

The research material consisted of 297 videos of bouts from the World Championships 2018 in Freestyle wrestling. These videos were posted by the United World Wrestling on their website. Samples were divided into three weight classes: lightweight categories – 57 kg, 61 kg, 65 kg, middleweight categories – 70 kg, 74 kg, 79 kg, 86 kg, and heavyweight categories – 92 kg, 97 kg, 125 kg as shown in Table 1. A video analysis software Kinovea [Polak *et al.* 2016] was used to investigate each wrestling bout. A single investigator, with more than 15 years of experience in wrestling, certified coach of wrestling, and a referee of national degree investigated bouts. Systematic bias between two observations or test and retest sessions were checked by performing a t-test.

Table 1. Distribution of weight classes

Weight class	Weight category	Number of bouts
Lightweight	57 kg	31
	61 kg	25
	65 kg	36
Middleweight	70 kg	33
	74 kg	35
	79 kg	28
	86 kg	35
Heavyweight	92 kg	24
	97 kg	28
	125 kg	22

Data are presented as mean, standard deviation, and 95 % confidence interval. Statistical significance was set at $p < 0.05$. The Kolmogorov-Smirnov test was used for the normality distribution of data. Kruskal-Wallis and Mann-Whitney U tests were conducted to compare the groups. SPSS software was used for data analysis.

Observed time-variables in wrestling bouts were:

— *Total bout time* [TBT] – average duration of a bout, including referee´s interruptions and 30-second rest between periods;

— *Total work time* [TWT] – average duration of a bout from the start of the bout until the end of the bout without referee´s interruptions, included 30-second rest between periods;

— *Total pause time* [TPT] – average duration of all referee´s interruptions in a bout and 30-second rest between periods;
— *Number of work periods* [NWP] – an average number of every work period per bout which was bounded by referee´s interruption or 30-second rest between periods;
— *Work period time* [WPT] – average duration of a work period per bout bounded by referee´s interruption or 30-second rest between periods;
— *Number of interruption periods* [NIP] – an average number of referee´s interruptions per bout;
— *Interruption period time* [IPT] – average duration of the interruption period per bout;
— *Rest* [R] – 30-second rest between periods;
— *Effort: Pause ratio* [EP] – calculated from total work time [TWT] and total pause time [TPT].

Reliability of observation was established according to the literature [Hopkins 2000]. The student t-test showed no significant differences in observed time-variables (P > 0.05) during the two analyses of one observer. The lack of difference between observations demonstrated that these indicators could be used effectively to record the time variables of top-level wrestlers.

Observed technical variables in wrestling bouts were used via reliable Time-Motion Analysis Model established by Lopez-Gonzalez and Miarka [2013]:
— *Standing position – preparation phase* [SPPP] – includes three action categories with the following criteria: motion – no contact between both wrestlers in standing positions; hand fighting – wrestlers make contact using only grips by palms to any part of their arms, shoulders, neck, and head; pummeling – use of a forearm in conjunction with arm ("hooking" and "locks") to hold opponent´s upper limbs (arm, torso, waist, or head, and arm together).
— *Standing position – execution phase* [SPEP] – includes three action categories with the following criteria: shot – an abrupt, surprise body movement displacing oneself towards opponent´s hips or knees level in order to reach the opponent legs, ankles or waist; standing technical body movement – starting from a segment control (a grip or tie-up), the attacking wrestler makes a movement with his own body in order to take down or throw the opponent on the ground and to score; push-out – a wrestler carry-out his opponent out of the passivity zone, without the use of a clearly standing technical body movement.
— *Par-terre position – preparation phase* [PPPP] – includes one action category with the following criteria: par-terre set-up – both wrestlers are in par-terre position, nobody is in a dangerous position and no concrete attack (gut-wrench, a cradle, etc) has started or has been attempted.
— *Par-terre position – execution phase* [PPEP] – includes one action category with the following criteria: par-terre technical body movement – the attacking wrestler makes a movement with his own body in order to put the opponent in a "dangerous position" (the opponent´s back exposed to the ground).
— *Dangerous position – control* [DPC] – has the following criteria: the offensive wrestler maintains his opponent in a "dangerous position" (opponent´s back facing the mat).
— *Preparation: Execution phase ratio* [PE] – calculated from the total time spent in standing [SPPP] and par-terre position [PPPP] during the preparation phase and standing [SPEP] and par-terre position [PPEP] during the execution phase.
— *Standing: par-terre position ratio* [SP] – calculated from the total time spent in standing position during preparation [SPPP] and execution [SPEP] phase and par-terre position during preparation [PPPP] and execution [PPEP] phase.

Results

The mean total bout duration [TBT] was 433 s, the length of the shortest and the longest bout was 19 s, and 1011 s, respectively. The mean duration of work [WT] and pause duration [TPT] was 304 s and 128 s, respectively. The effort: pause ratio [EP] was determined at 2.4:1. The mean duration of work [WPT] and interruption periods [IPT] was 38 s ± 79.5 and 12 s ± 76.1 s, respectively. The average number of work periods [NWP] was 8 ± 17. The total mean duration of rest [R] was 43 s ± 267 s.

The time characteristics of bouts according to weight classes did not differ significantly (Table 2.).

The mean total time spent in the standing position during the preparation phase [SPPP] was 239 s ± 352 s. The mean total time spent in the standing position during the execution phase [SPEP] was 32 s ± 114 s. The mean total time spent in the par-terre position during the preparation phase [PPPP] was 20 s ± 80 s. The mean total time spent in the par-terre position during the execution phase [PPEP] was 10 s ± 88 s. The mean total time spent in a controlled dangerous position [DPC] was 1 s ± 48 s. The standing and par-terre position ratio was determined at 9:1. The preparation and execution phase ratio was determined at 6:1.

The technical characteristics of bouts according to weight classes differed significantly in the mean total time spent in the standing position during the execution phase [SPEP] ($P<0.05$, $H=0.000$). The statistical difference was observed between *lightweights* and *heavyweights* ($p<0.05$, $U=0.000$) and between *middleweights* and *heavyweights* ($p<0.05$, $U=0.006$) (Table 3.).

Table 2. Time characteristics of bouts divided by weight classes

Variables	Light-weight	Middle-weight	Heavy-weight	Kruskal-Wallis *H* value
[TBT] s	445 ± 173 (410 to 481)	431 ± 154 (404 to 458)	421 ± 157 (385 to 458)	0.744
[WT] s	307 ± 96 (287 to 327)	307 ± 92 (291 to 323)	300 ± 92 (291 to 323)	0.991
[TPT] s	139 ± 104 (117 to 160)	125 ± 85 (110 to 140)	122 ± 77 (104 to 139)	0.677
[NWP] n	9 ± 3 (8 to 9)	8 ± 3 (8 to 9)	8 ± 3 (7 to 9)	0.852
[WPT] s	38 ± 11 (36 to 40)	38 ± 11 (36 to 40)	39 ± 12 (36 to 42)	0.892
[NIP] n	7 ± 3 (6 to 7)	7 ± 3 (6 to 7)	6 ± 3 (6 to 7)	0.828
[IPT] s	14 ± 12 (11 to 16)	12 ± 8 (10 to 13)	12 ± 9 (10 to 14)	0.263
[R] s	41 ± 19 (37 to 45)	44 ± 27 (40 to 49)	43 ± 21 (39 to 48)	0.087
[EP]	2.2:1	2.4:1	2.5:1	

Data are presented as mean ± standard deviation; 95%CI: 95 % confidence interval are presented between parenthesis; TBT: total bout time; WT: work time; TPT: total pause time; NWP: number of work periods; WPT: work period time; NIP: number of interruption periods; IPT: interruption period time; R: rest; EP: effort: pause ratio; s: seconds; n: amount. No statistical significance among weight classes.

Table 3. Technical characteristics of bouts divided by weight classes

Variables	Light-weight	Middle-weight	Heavy-weight	Kruskal-Wallis *H* value
[SPPP] s	236 ± 85 (219 to 254)	238 ± 92 (222 to 253)	244 ± 95 (222 to 265)	0.342
[SPEP] s	38 ± 24 (33 to 43)[a]	32 ± 20 (29 to 36)[b]	25 ± 17 (21 to 29)	0.000**
[PPPP] s	20 ± 14 (17 to 23)	22 ± 17 (19 to 25)	20 ± 16 (16 to 23)	0.410
[PPEP] s	11 ± 12 (8 to 13)	11 ± 14 (9 to 14)	10 ± 13 (7 to 13)	0.487
[DPC] s	2 ± 5 (1 to 2)	1 ± 5 (0 to 2)	1 ± 4 (0 to 2)	0.759
[PE]	5.2:1	6:1	7.5:1	
[SP]	8.8:1	8.2:1	9:1	

Data are presented as mean ± standard deviation; 95%CI: 95 % confidence interval are presented between parenthesis; SPPP: standing position – preparation phase; SPEP: standing position – execution phase; PPPP: par-terre position – preparation phase; PPEP: par-terre position – execution phase; DPC: dangerous position – control; PE: preparation: execution phase ratio; SP: standing: par-terre position ratio; s: seconds; ** (P<0.01); a: Mann-Whitney U (p<0.05, U =0.000); b: Mann-Whitney (p<0.05, U =0.006).

Discussion

The goal of this study was to evaluate the effort and pause ratio during Freestyle wrestling bouts during the World Championships 2018. To the best of our knowledge, this is the first attempt of time-motion analysis in Freestyle wrestling to present the effort and pause ratio.

The mean duration of a whole bout was 433 s (range 19-1011 s), similar results were observed by Nilsson *et al.* [2002] at the 1998 World Championships, where the mean duration of a bout was 427 s (range 324-535 s). The extension of range in bout duration in our study compared to Nilsson *et al.* [2002] may be influenced by current rules that allow coaches to use "challenge" [Middleton *et al.* 2013; United World Wrestling 2018]. An injury treatment may cause this difference as well. The bout duration may be influenced by athletic, technical, tactical, and psychological readiness and the individual method to compete [Miarka 2016].

The mean work time without interruptions was 304 s (range 19-360 s) per bout. Almost the same results were found by Markovic *et al.* [2017] at European games 2015 (302 s). According to Arabaci *et al.* [2018], work time at the 2016 Rio Olympic Games in Freestyle was 319 s. In Greco-roman wrestling, work time was 317 s [Nilsson *et al.* 2002]. We can say that with current rules (2 three-minute periods) [United World Wrestling 2018] work time does not differ from Nilsson´s *et al.* [2002] research when a wrestling bout consisted of 1 five-minute period. Thus, the change of rules (1 five-minute period, 2 three-minute periods) has no impact on the mean work time. The mean pause time was 128 s (range 0 – 651 s), in Nilsson´s *et al.* [2002] research the mean pause time was 110 s. The longer mean pause time may be caused by the current rules when a bout is not just interrupted by the referee´s decision, but also by 30 s rest between periods. The size of the range of pause time may be influenced by a challenge, or injury treatment [United World Wrestling 2018]. An interesting finding is that the mean rest time was 43 s. Approximately 5 minutes of rest is required for complete adenosine triphosphate/phosphocreatine resynthesis, with about 93% of adenosine triphosphate/phosphocreatine recovering in the first two minutes, and the remaining 7% recovering very slowly. In our case, the mean rest time (43 s) is therefore insufficient for a complete recovery of energy reserves, so with the gradually increasing time of the bout other methods of energy payment (anaerobic glycolysis, or oxidative methods), however, the load intensity naturally decreases [Bompa, Buzzichelli 2018]. Thus lactic acid energy system is the determinant factor in wrestling performance [Mirzaei *et al.* 2017].

According to mean work time and mean pause time the effort and pause ratio was determined at 2.4:1. Nilsson *et al.* [2002] determined the effort and pause ratio at 2.5:1. A similar ratio was observed in judo (range 2:1

– 3:1) [Van Malderen *et al.* 2006, Miarka *et al.* 2012]. To compare with striking combat sports, kickboxing showed the effort and pause ratio to 1:1 [Ouergui *et al.* 2014].

An average number of work periods per bout was 8, with an average time 38 s, an average interruption period time was 12 s. According to this finding, it is important to use the effort and pause ratio knowledge, by creating the training programs in the competition period.

According to weight classes, there were no statistical differences in time characteristics of bouts [TBT, WT, TPT, NWP, WPT, NIP, IPT, R]. Based on this finding, we can say there is no need to divide training programs, in this age category, separately for the weight classes.

According to the technical characteristics of bouts, the most overall time spent in the competition was in the standing position in the preparation phase (239 s), an average time in a standing position during the execution phase was 32 s. In the par-terre position, the preparation phase was on average 20 s and the execution phase was 10 s. The standing and par-terre position ratio was determined at 9:1. These findings agree with Dokmanac *et al.* [2012] when most of the techniques in Freestyle wrestling are executed in the standing position. The preparation and execution phase ratio was determined at 6:1. This ratio links with [Lopez 2018] findings that on average, 1 technique is executed per minute.

A statistical difference was found in the standing position during the execution phase among weight classes. A group of the heavyweight class has shown a significantly lower time spent in the execution phase. The reason may be that heavyweight wrestlers tend to attack less than middle or light weights, with a higher success rate [Kruszewski *et al.* 2011].

Limitations of the study

This study only included data from the Senior World Championships 2018, which may limit the generalisability of the findings (we did not focus on international competitions, where more than one wrestler from the same country can compete).

Conclusion

The present study is the first to show the effort and pause ratio in Freestyle wrestling. Our study indicates that the effort and pause ratio is 2.4:1. An important finding for coaches is the number of work periods during bouts (8) with an average of 38s work duration and 12s rest. Most of the bout time is spent in the standing position during the preparation phase (239 s). The preparation and execution phase is 6:1. There were no statistical differences in the observed time characteristics of bouts among the weight classes. We have found a statistical significance in the technical characteristics of bouts - the heavyweight wrestlers spent less time in the standing position during the execution phase. The effort and pause ratio for lightweight, middleweight, and heavyweight were 2.2:1, 2.4:1, and 2.5:1, respectively. The results of our study can be used to prescribe physical training, considering weight classes.

There is a need to conduct a time-motion analysis of a high-level wrestling competition to the objectification to validate this study. Due to the different time duration of bouts in younger age categories, a separate time-motion analysis is needed.

Ethical consideration of the study

All videos of bouts of the World Championships 2018 in Freestyle wrestling are available, thus there was no need for ethical committee assessment.

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Analiza ruchu w czasie w zapasach w stylu wolnym (freestyle): Kategoria wagowa jako czynnik różnej struktury ruchu w czasie

Słowa kluczowe: mistrzostwa świata, seniorzy, wysiłek, pauza, United World Wrestling

Streszczenie:

Tło. Wiedza na temat struktury czasowo-ruchowej walk w zapasach *freestyle* jest ograniczona.

Problem i cel. Głównym celem niniejszego badania było określenie współczynnika wysiłku i pauzy/przerwy w zapasach w stylu dowolnym.

Metody. Przeanalizowano 297 walk z Mistrzostw Świata 2018 w zapasach *freestyle*. Walki zostały podzielone na trzy kategorie wagowe (lekka, średnia, ciężka). Do analizy ruchu w czasie wykorzystano oprogramowanie Kinovea.

Wyniki. Stosunek wysiłku do przerwy/pauzy określono na 2,4:1. Liczba okresów działania w czasie walki wynosiła 8. Większość czasu walka była prowadzona w pozycji stojącej podczas fazy przygotowawczej. Zawodnicy wagi ciężkiej spędzali statystycznie istotnie mniej czasu w pozycji stojącej w czasie walki w porównaniu z zawodnikami wagi lekkiej i średniej. Współczynnik wysiłku i przerwy/pauzy dla wagi lekkiej, średniej i wagi ciężkiej określono odpowiednio na 2,2:1, 2,4:1 i 2,5:1.

Wnioski. Wyniki badania można wykorzystać do przepisania treningu fizycznego. Potrzebne są przyszłe analizy ruchu w czasie.