REVIEW ARTICLE

Strength profile in wrestlers – a systematic review

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

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Abstract

Background and Study Aim: Success in wrestling depends on many different factors, but strength could be considered as the most important one. Different strength indicators are closely related to high-level wrestling performance. The aim of this review is to generalize the recommendations of the authors of works dedicated to the analysis of muscle strength in wrestlers, regardless of style (Greco-Roman and freestyle) and knowledge of the most commonly used tests to assess the various manifestations of this motor ability

Material and Methods: The search and the analysis of the studies were done in accordance to PRISMA guidelines. A literature search of 3 databases (Google Scholar, PubMed and Science Direct) was conducted. The identified studies had to meet the following criteria: year of publication (2010-2021), published in English, wrestlers as sample of participants, who do not suffer from acute and chronic injuries.

Results: A total of 24 papers were included to analyses, with a total of 1254 participants, both genders. Greco-Roman style participants were 530, while freestylers were 529. Hand grip strength conducted 18 studies, explosive power of legs 12 studies, basic motor tests 8 studies, 1RM squat and bench 4 studies, isokinetic strength conducted 4 studies and isometric strength only once. The most commonly used test to assess different types of strength in wrestlers are handgrip strength, isometric and isokinetic strength, 1RM bench and squat, explosive strength of legs tests and basic motor tests.

Conclusions: The authors cannot with certainty determine an optimal wrestlers profile, but this review can serve as an framework for eventual practical preparation for the demands of competition.

Key words: 1RM • Greco-Roman • exercise • explosive power • freestyle • motor tests • weight category

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INTRODUCTION

Wrestling was an important part of the ancient Olympic Games and is still one of the more popular events of the modern Olympic Games [1]. This combat sport is based on a weight class system which aims to balance out the physical characteristics between wrestlers and therefore increase the percentage of performance that depends on technical and psychological skills [2]. Currently, Greco-Roman that is acknowledged as the classic style and freestyle are the two internationally recognized forms of competitive wrestling. Greco-Romans wrestlers are permitted only to attack and to use their upper body and, then, holds below the waist are forbidden, whereas in freestyle are permitted to use their whole body during competition [3].

This is a sport that belongs in group of speed-strong nature [4], hence, the main goal of any wrestler is to gain dominance over the opponent and to provide complete physical control over him [3]. Consequently, to be successful in international competitions, wrestling athletes need a high level of physical fitness [5]. In addition, the importance of motor or functional ability is depending on age. In children, the most important ability is coordination, while in seniors, it is strength, as well as strength endurance [6]. Also, it can depend on weight category, where strength is most important factor in heavy weight, relative to lighter categories [6–8].

One match consists of alternating repetition of high-intensity activity (attacks and counterattacks) and low-intensity activity or rest [2] and that is why these characteristics of wrestling require a wide range of motor skills [9]. In assessments, wrestlers are shown to be the strongest athletes based on body weight [10]. There is a strong correlation between wrestling performance and strength [11]. Strength in wrestling is important in both, an offense and defence phases [2]. Same author also stated that successful wrestlers exhibit greater dynamic isokinetic strength than unsuccessful wrestlers.

Success in wrestling depends on many external factors, but most important component is strength (maximal, explosive, repetitive and static), then speed [9], coordination and balance [12], as well as flexibility [13, 5, 14]. On the other hand, Starosta & Tracewski [15] put coordination first based on their analysis, and accordingly, a battery of tests [16] was made which has wide application. Any sport that include exercise and combat within a short period of time, requires high level of total body strength [17].

In this branch where physical and motor features are very prominent, it is important to know how these characteristics affect each other, and to control choice of skills and exercise planning [18]. Baić [19] have found discriminant function which differs two completely quality groups of wrestlers (Polish and Croatian). He calls this discriminatory function „endurance in strength", „strong endurance" or „strength endurance". He also describes it as the possibility of repeating a procedure that requires maximum strength, such as lifting from the ground, which is equivalent to the classic lifting of weights.

The main element of the wrestling technique is the attack phase, the goal of which is to achieve superiority over the opponent [20, 21]. During offensive and defensive activities in the combat, a high level of maximum strength is manifested [22, 23]. Also, postural control has an important role in wrestling, and proficiency in postural control may determine successful performance [24]. To perform well, core stabilization is necessary to withstand the shear forces on the spine that occur in multidirectional movements [25].

Strength evaluation during exercises enables control and the possibility of strength improvement [26]. In order to effectively improve the state of strength during the wrestler training process, the use of a specialized methodology is required [4]. Moreover, understanding the characteristics of elite wrestlers can provide insightful information regarding what is needed for competitive success. According to the authors, there is no study that summarize strength in wrestlers, based on which it can be concluded which tests are most often used to assess strength.

The aim of this review is to generalize the recommendations of the authors of works dedicated to the analysis of muscle strength in wrestlers, regardless of style (Greco-Roman and freestyle) and knowledge of the most commonly used tests to assess the various manifestations of this motor ability.

Freestyle wrestling – is a style of amateur wrestling that is practiced throughout the world. Along with **Greco-Roman**, it is one of the two styles of wrestling contested in the Olympic games.

Strength – *noun* the fact of being strong [91].

Strength training – *noun* training that aims to build muscle strength, usually resistance training [91].

Endurance – *noun* the ability or power to bear prolonged exertion, pain or hardship endurance athlete [91].

Exercise – *noun* **1.** physical or mental activity, especially the active use of the muscles as a way of keeping fit, correcting a deformity or strengthening a part **2.** a particular movement or action designed to use and strengthen the muscles ■ *verb* **1.** 7o undertake physical exercise in order to keep fit and healthy **2.** to subject the body, or part of it, to repetitive physical exertion or energetic movement in order to strengthen it or improve [91].

Motor skills – *plural noun* the ability of a person to make movements to achieve a goal, with stages including processing the information in the brain, transmitting neural signals and coordinating the relevant muscles to achieve the desired effect [91].

Technique– *noun* a way of performing an action [91].

PRISMA – Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

PEDro – Physiotherapy Evidence Database.

CMJ – countermovement jump.

SJ – squat jump.

LJ – long jump.

DJ – drop jump.

1RM – individual's maximal strength or 1 repetition maximum [92].

MATERIAL AND METHODS

Literature identification

The PROSPERO registration number for this review is 281 097. The search and analysis of the studies were done in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [27, 28]. Studies from 2010 to 2021 were included, and the following databases were searched for the appropriate and adequate literature: Google Scholar, PubMed and Science Direct.

The following keywords were used to search for the articles reporting on strength indicators in wrestlers: ("wrestling" OR "freestyle wrestling" OR "greco-roman wrestling") AND ("strength" OR "strength profile" OR "exercise" OR "explosive power" OR "fitness" OR "physical fitness") AND ("dynamometry" OR "1RM") AND ("olimpic" OR "elite" OR "professional" OR "college" OR "amateur").

A descriptive method was used to analyse the obtained data, and all titles and abstracts were reviewed for potential inclusion of studies. At the same time, the identification strategy was modified and adapted to each database in order to increase the sensitivity. The sensitivity, i.e. the search filters in every database were based on year of publication, which was set from 2010 until 2021 and studies conducted strength variables in Greco-Roman and freestyle wrestlers. After a detailed identification, relevant studies were obtained if they met the inclusion criteria.

The search for studies were accordingly of their value, and data extraction were conducted independently by two authors (Dušan Đorđević and Mima Stanković), and the lists of references from previously assessed and original research were also reviewed. After that, each author cross-examined the found works, which were then taken for further analysis or rejected.

Inclusion criteria of studies

The identified studies were analysed, and in order for the study to be included in the final analysis, they had to meet the following criteria: year of publication, study published in English, the sample of participants had to train wrestling, who do not suffer from acute and chronic injuries. There were no exclusion criteria for gender, years of training, weight categories, type of wrestling nor rank of the competition, as well as that different strength variables were applied in the studies.

Bias risk assessment

The risk of bias was assessed according to the Physiotherapy Evidence Database to determine the quality of clinical trials (PEDro scale). This scale was developed to identify trials that are likely to be internally valid and have sufficient statistical information to guide clinical decision-making. It is a valid measure of the methodological quality of clinical trials, a valid way to sum scale item scores to obtain the total score that can be treated as interval level measurement and subjected to parametric statistical analysis [29]. Based on the points each study scored on the PEDro scale, final study quality assessment scores were defined. With a grand total of 0-3 points, studies are classified as "poor", 4-5 "fair", 6-8 "good" and 9-10 "excellent". In addition, for studies evaluating complex interventions (e.g., exercise), a total score of 8/11 may be optimal [30].

Two independent authors assessed the quality and risk of bias using checklists. Consent between them was assessed using k statistical data to screen the full text and assess relativity and bias risk. In case of disagreement about the risk of bias, data verification was performed by a third author, who also gave the final decision.

Data extraction

After cross-examination, information was extracted and then moved to an excel spreadsheet if the data were adequate. Cochrane Consumer and Communication Review Group's standardized data extraction protocol was applied to extract study characteristics, including authors and year of study, information such as sample size, age, exercise program, strength variables and study results. In addition, the initial search was based on already known strength variables only, while after identified studies who were assessed for eligibility, the new strength variables appeared. Then, in agreement with other co-authors, the outcomes were extended and the final outcomes were: hand grip, leg and back strength on dynamometer, 1RM back and squat test, explosive strength of legs, basic motor tests, as well as isometric and isokinetic strength.

Selection and characteristics of studies

A search of electronic databases and scanning the reference lists yielded 502 relevant studies. After removing duplicates, 447 studies were screened. Based on the inclusion criteria, 64 studies were

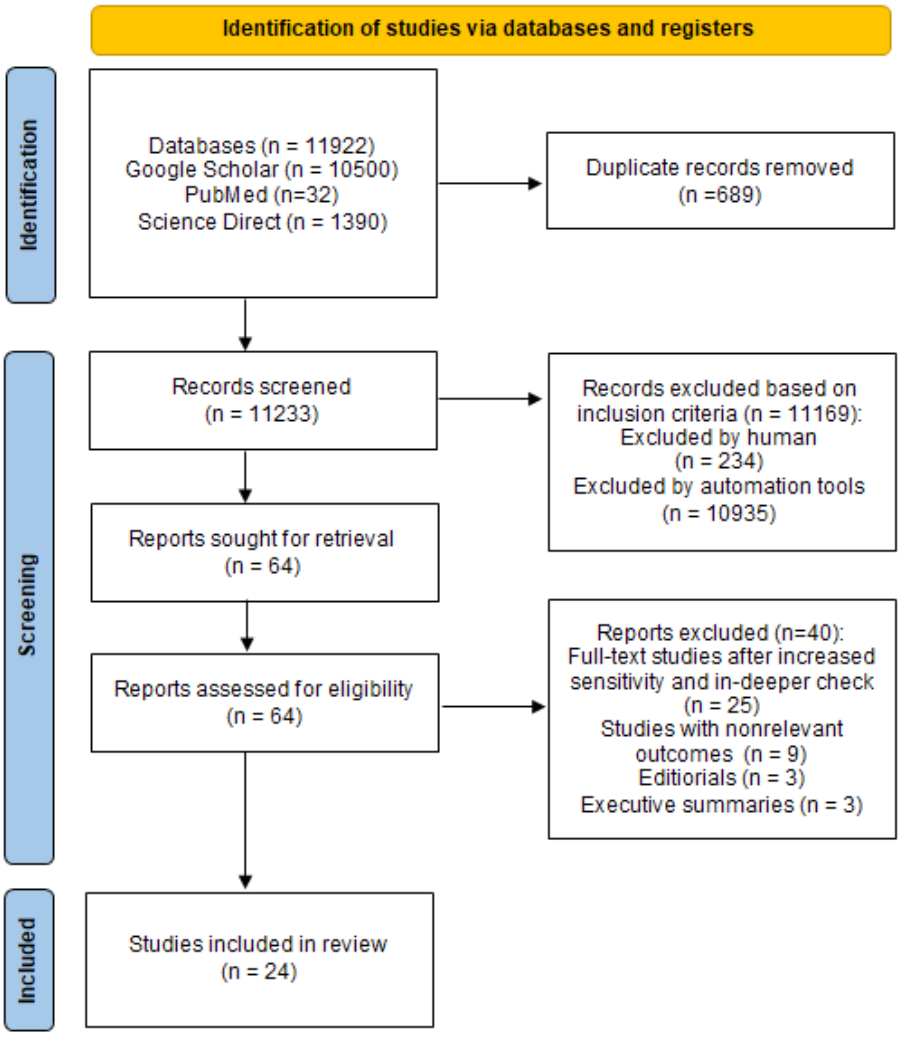

Figure 1. Collecting adequate studies on the basis of pre-defined criteria (PRISMA flow chart).

selected and screened for eligibility. In the end, 24 of them were included. Figure 1 (PRISMA flow diagram) shows the process of collecting suitable studies based on the predefined criteria.

Ethics approval

This study was approved by the Ethics Committee of Faculty of Sport and Physical Education, University of Niš (Serbia).

RESULTS

All 24 studies [6, 31, 11, 32, 33, 23, 34-41, 5, 42-45, 21, 46-49] included in this quantitative analysis were cross-sectional (Table 1). The k rate of consent was k = 0.94.

There were a total of 1254 participants, 1207 males and 47 females. In all included studies, the highest number of participants was 168 [48], while the lowest was 11 [43]. In two studies [23, 34], the sample of participants consisted of females only, mixed gender sample was in one study [44], while in rest of included studies, the sample of participants consisted of males only (Table 2).

Youngest participants had 10 years [45], while the oldest one had 27.9 years [37]. Total number of Greco-Roman style participants were 530, while freestylers were 529. In the remaining 195 participants, there were no further information's about style of competing.

Table 1. Results of analysis based on PEDro Scale for cross-sectional studies.

Study, year	Criteria											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Σ**
Starosta et al. [6] 2010	Y	N	N	Y	N	N	N	Y	Y	Y	Y	**5**
Barbas et al. [31] 2011	Y	N	N	N	N	N	N	Y	Y	Y	Y	**4**
Garcia-Pallares et al. [11] 2011	Y	N	Y	Y	Y	N	N	Y	Y	Y	Y	**7**
Demirkan et al. [32] 2012	Y	N	N	N	Y	N	N	Y	Y	Y	Y	**5**
Garcia-Pallares et al. [33] 2012	Y	N	N	Y	N	N	N	Y	Y	Y	Y	**5**
Yoon, [23] 2012	Y	N	N	N	N	N	N	Y	Y	Y	Y	**4**
Zi-Hong et al. [34] 2013	Y	N	Y	N	N	N	N	Y	Y	Y	Y	**5**
Basar et al. [35] 2014	Y	N	N	N	Y	N	N	Y	Y	Y	Y	**5**
Demirkan et al. [36] 2014	Y	N	N	Y	Y	N	N	Y	Y	Y	Y	**6**
Ramirez-Velez et al. [37] 2014	Y	N	N	N	N	N	N	Y	Y	Y	Y	**5**
Arslanoglu, 2015 [38] 2015	Y	N	N	N	N	N	N	Y	Y	Y	Y	**4**
Demirkan et al. [39] 2015	Y	N	N	Y	N	N	N	Y	Y	Y	Y	**5**
Rahmat et al. [40] 2016	Y	N	N	N	N	N	N	Y	Y	Y	Y	**4**
Bayraktar & Koc [41] 2017	Y	N	Y	Y	N	N	N	Y	Y	Y	Y	**6**
Nikooie et al. [5] 2017	Y	N	Y	Y	N	N	N	Y	Y	Y	Y	**6**
Yamashita et al. [42] 2018	Y	N	N	Y	N	N	N	Y	Y	Y	Y	**5**
Yildiriim et al. [43] 2019	Y	N	Y	N	N	N	N	Y	Y	Y	Y	**5**
Venegas-Cardenas et al. [44] 2019	Y	N	N	N	N	N	N	Y	Y	Y	Y	**4**
Acar & Ozer [45] 2020	Y	N	N	N	N	N	N	Y	Y	Y	Y	**4**
Aksoy et al. [21] 2020	Y	N	N	N	N	N	N	Y	Y	Y	Y	**4**
Ozbay & Ulupinar [46] 2020	Y	N	Y	Y	N	N	N	Y	Y	Y	Y	**6**
Podrihalo et al. [47] 2020	Y	N	N	Y	N	N	N	Y	Y	Y	Y	**5**
Cieslinski et al. [48] 2021	Y	N	Y	Y	N	N	N	Y	Y	Y	Y	**6**
Tatlici et al. [49] 2021	Y	N	N	N	N	N	N	Y	Y	Y	Y	**4**

Legend: **1** eligibility criteria were specified, **2** subjects were randomly allocated to groups, **3** allocation was concealed, **4** the groups were similar at baseline regarding the most important prognostic indicators, **5** there was blinding of all subjects, **6** there was blinding of all therapist who administered the therapy, **7** there was blinding of all assessors who measured at least one key outcome, **8** measures at least one key outcome were obtained from more than 80% of the subjec37, ts initially allocated to the group (dropouts), **9** all subjects for whom outcome measures were available received the treatment or control conditions as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat", **10** the results between-group statistical comparisons are reported for at least one key outcome, **11** the study provides both point measures and measures of variability for at least one key outcome, **Y** criterion is satisfied, **N** criterion is not satisfied; **Σ** total points awarded

Table 2. Results of studies included in qualitative analysis.

Study, year	Participants		Strength variables	Results	
	number and groups	age (years)			
Starosta et al. [6] 2010	M-107 (Jun) Gr-61 Fr-46	17-20	1RM (B, Sq) Pup Su CMJ	Gr: 1RM (B)-92.66 ±18.74 1RM (Sq)-111.71 ±21.58 Pup-14.83 ±8.84; Su-18.45 ±9.92; CMJ-53.93 ±5.63	Fr: 1RM (B)-107.68 ±23.27; 1RM (Sq)-117.44 ±30.15; Pup-22.14 ±8.26; Su-30.13 ±11.41; CMJ-57.41 ±7.68
Barbas et al. [31] 2011	M-12 (E, Gr)	22.1 ±1.3	GS VJ BD	VJ: Match1 (41.7 ±1.9 to 42 ±2.8cm); Match2 (40.4 ±2.5 to 40.9 ±2.1cm); Match3 (38.6 ±2,8 to 26.8 ±2.3cm)* Match4 (34.9±2.3* to 23.1 ±2.9cm); Match5 (37.9 ±2.6 to 37.3 ±2.8cm) BD: Match1 (217.5 ±7.2 to 208.3 ±5.5kg); Match2 (209.4 ±5.8 to 198.6 ±4.8kg); Match3 (201.6 ±5.2 to 175.9 ±5kg); Match4 (189.2 ±4.1* to 161.3 ±3.8kg); Match5 (199.6 ±4.5 to 172.7 ±4.7kg)	GS: Match1 (55.1 ±2.6 to 47.7±2.3kg**); Match2 (52.8 ±2.2 to 44.8 ±2.7kg**); Match3 (47.9 ±2.1* to 39.5 ±1.9kg**); Match4 (45.1 ±1.6** to 35.3 ±2kg*); Match5 (47.6 ±1.7** to 38.9 ±1.6kg*)
Garcia-Pallares et al. [11] 2011	M-92 Gr-53 Fr-39 LW(A)-15 LW(E)-18 MW(A)-19 MW(E)-18 HW(A)-12 HW(E)-10	LW(A)-16.1 ±1 LW(E)-17.5 ±1.1 MW(A)-17.1 ±1.8 MW(E)-18.5 ±1.5 HW(A)-17.2 ±1.7 HW(E)-19.6 ±1.5	CMJ GS BD 1RM (B, Sq)	CMJ: LW(A)-31 ±83.3cm* LW(E)-35.4 ±6.7cm; MW(A)-31.9 ±3.8cm* MW(E)-35 ±3.5cm HW(A)-29.6 ±3.8cm* HW(E)-35.5 ±4.4cm GS (PH): LW(A)-39.7 ±8kg* LW(E)-45 ±6.5kg; MW(A)-46.5 ±8kg***; MW(E)-53.1 ±7.8kg; HW(A)-52.1 ±9.5kg* **HW(E)-55.6 ±8.9kg	GS (NPH): LW(A)-36.4 ±7kg*; LW(E)-44.9 ±7.3kg MW(A)-43.4 ±7.9kg* **MW(E)-49.1 ±8.8kg HW(A)-49.3 ±11.1kg* **HW(E)-55.9±6.7kg BD: LW(A)-98.3 ±17.6kg* LW(E)-123.6 ±14.6kg MW(A)-121.8 ±15.3kg* **MW(E)-126.3 ±14.6kg HW(A)-134.4 ±10.4kg* **HW(E)-148.1 ±11.2kg
Demirkan et al. [32] 2012	M-48 (Gr) Nt-11 Ns-37	Nt-19.3±10 Ns-18.8±1	GS LD BD	Nt: GS(R)-54 ±8kg; GS(L)-53 ±7.8kg; BD-163 ±22kg; LD-171 ±23kg	Ns: GS(R)-49 ±8kg; GS(L)-48 ±7.9kg; BD-144 ±22kg; LD-160 ±22kg
Garcia-Pallares et al. [33] 2012	M-35 LW(E)-6 LW(A)-12 MW(E)-7 MW(A)-10	LWE-18.2 ±0.8 LWA-16.8 ±1.1 MWE-18.7 ±1.5 MWA-16.9 ±1.3	CMJ GS(D, ND) 1RM (B, Sq) BD	CMJ: LW(E)-23 ±2.1cm; LW(A)-22.5 ±3.8cm; MW(E)-26.5 ±2.4cm; MW(A)-24 ±2.7cm*; GS(D); LW(E)-30.9 ±5.2cm; LW(A)-26.9 ±5.4cm*; MW(E)-34.7 ±6.3cm**; MW(A)-32.9 ±3.7cm	GS(ND): LW(E)-30.1 ±6cm LW(A)-26.3 ±4.5cm*; MW(E)-33.9 ±5.7cm; MW(A)-30.4 ±2.7cm*; BD: LW(E)-97.5 ±10.5cm; LW(A)-84.6 ±15.3cm*; MW(E)-116 ±10.2cm**; MW(A)-104.1 ±7.5cm***; E, 1RM(B, Sq) 13.4 to 33.1%
Yoon [23] 2012	F-16 (Coll) E1-6 E2-10	E1-19.7±0.8 E2-19.5±1.6	KFs KEs	E1(180°/sec); KEs(R)-193.7 ±34.8; KEs(L)-208.7±31.7; KFs(R)-123.8 ±37; KFs(L)-128.3 ±57.6; E2(180°/sec) KEs(R)-230.1±24.6 KEs(L)-228.3±34.6 KFs(R)-146.9±50.3 KFs(L)-135.7±35.1	E1(240°/sec); KEs(R)-2604.7 ±248.1; KEs(L)-2678.8 ±399.4; KFs(R)-1676.3 ±404.7; KFs(L)-1787.7 ±473.4; E2(240°/sec); KEs(R)-2925.7 ±374.2; KEs(L)-2751.2 ±314.7; KFs(R)-1879.1 ±638.9; KFs(L)-2096.7 ±436.8
Zi-Hong et al. [34] 2013	F-25 (E, Fr) 48kg-8 55kg-5 63kg-5 72kg-7		ISOKsL ISOKsE ISOKsB ISOKsS 1RM (Sq)	1RM (Sq) 48kg-90±4kg 55kg-100±12 63kg-99±17 72kg-106±8 L,Flex, ISOsS(60°)-49±10Nm L,Flex, ISOsS(180°)-52±13Nm	R,Flex, ISOsS(60°)-53±12Nm R,Flex, ISOsS(180°)-57±13Nm L,Ext, ISOsS(60°)-86±13Nm L,Ext, ISOsS(180°)-85±14Nm R,Ext, ISOsS(60°)-82±17Nm R,Ext, ISOsS(180°)-86±18Nm
Basar et al. [35] 2014	M-81 Gr-35 Fr-46	LW(F)-18.2 ±0.8 LW(Gr)-18.3 ±1 MW(F)-18.8 ±0.9 MW(Gr)-18.7 ±0.7 HW(F)-19 ±0.9 HW(Gr)-18.8 ±0.9	GS LD	GS: LW(F)-114.4 ±16.7kg; LW(Gr)-126.8 ±21.8kg; MW(F)-129.4 ±17.7kg; MW(Gr)-138.1 ±9.9kg; HW(F)-148.3 ±21.5kg*; HW(Gr)-162.4 ±19.3kg*	LD: LW(F)-169.7 ±34kg; LW(Gr)-181.9 ±24.1kg; MW(F)-193.1 ±31.2kg; MW(Gr)-203.2 ±22.9kg; HW(F)-222.6 ±20.7kg*; HW(Gr)-272 ±19.3kg*

Study, year	Participants		Strength variables	Results	
	number and groups	age (years)			
Demirkan et al. [36] 2014	M-126 Gr-56 Fr-70	Gr-16.4±0.7 F-16.5±0.6	GS LD BD	F: GS(R)-43.9 ±9.1kg; GS(L)-43.4 ±8.8kg; BD-148 ±39kg; LD-180± 40kg	Gr: GS(R)-45.7 ±9.3kg; GS(L)-44.6 ±9kg; BD-154 ±26kg; LD-204±32kg
Ramirez-Velez et al. [37] 2014	M-21 (E)	27.9 ±6.7	CMJ LJ	CMJ-14.2 ±5.2cm LJ-217.4 ±12.1cm	
Arslanoglu, [38] 2015	M-48 (Gr)	18.61 ±1.01	VJ GS LD BD	VJ-63.2 ±6.20cm; GS(R)-52.68 ±9.87kg-f GS(L)-50.89 ±10.17kg-f; LD-179.48 ±35.36kg-f BD-153.98 ±25.92kg-f	
Demirkan et al. [39] 2015	M-126 Gr-56 Fr-70 LW(E)-15 LW(A)-31 MW(E)-12 MW(A)-32 HW(E)-11 MW(A)-25	LW(E)-16.3±0.8 LW(A)-16.2±0.7 MW(E)-16.5±0.7 MW(A)-16.5±0.5 HW(E)-16.7±0.6 MW(A)-16.6±0.6	GS LD BD	LW(E): GS(R)-36.6 ±7.2kg; GS(L)-35.2 ±7.2kg; BD-122 ±18.8kg' LD-165 ±29kg LW(A): GS(R)-37.4 ±6.8kg GS(L)-37.2 ±7kg; BD-123 ±30kg; LD-170±32kg MW(E): GS(R)-47.2 ±5.6kg; GS(L)-46.8 ±5.6kg; BD-157 ±16kg; LD-192 ±24kg	MW(A): GS(R)-44.7 ±6.2kg; GS(L)-43.8 ±5.5kg; BD-151 ±20kg; LD-185 ±32kg; HW(E): GS(R)-54.1 ±8.2kg; GS(L)-53.5 ±5.7kg; BD-185 ±20kg; LD-185 ±40kg; HW(A): GS(R)-53.1 ±5.9kg; GS(L)-52 ±5.4kg; BD-184 ±29kg; LD-226 ±34kg
Rahmat et al. [40] 2016	M-16 (E)	17.43±1.15	Pup Su 1RM (B, Sq)	Pup-11.18 ±3.31; Su-49.25 ±5.25; 1RM(B)-71.88 ±13.73kg; 1RM(Sq)-100.27 ±18.07kg	
Bayraktar et al. [41] 2017	M-36 Gr-19 Fr-17	Gr-23.6 F-23.7	GS LD CMJ SJ LJ DJ	Gr: GS(R)-0.64 ±0.78; GS(L)-0.63 ±0.97; LD-2.21 ±0.21; SJ-38.59 ±4.05cm; CMJ-39.71 ±4.46cm; DJ-39.81 ±5.40cm	F: GS(R)-0.68 ±0.96; GS(L)-0.67 ±0.13; LD-2.12 ±0.62; SJ-36.95 ±4.31cm; CMJ-39.70 ±3.97cm; DJ-41.14 ±7.04cm
Nikooie et al. [5] 2017	M-28 (Gr) Jun (Succ-5, Lsucc-7) Sen (Succ-5, Lsucc-9)	Jun (Succ-19.1 ±0.7, Lsucc-18.75 ±0.5) Sen (Succ-25.6 ±1.9, Lsucc- 25.5 ±2.5)	GS CMJ Pup Su	Jun(Succ); Pup-23.7 ±4.9; CMJ-58.6 ±6.5cm; GS(D)-0.57 ±0.06kg; Jun(Lsucc) Pup-16.37 ±3.88*; CMJ-55.3 ±4.2cm; GS(D)-0.49 ±0.05kg*	Sen(Succ) Pup-31.8±4.9*; Su-58.2 ±3.9 GS(D)-0.59 ±0.04kg*; Sen(Lsucc) Pup-26.1 ±4.8; Su-52.4 ±6.9; GS(D)-0.52 ±0.059kg
Yamashita et al. [42 2018	M-21 (Fr) Inter-11 Coll-9	Inter-23.9±3.8 Coll-19.6±1	ISNFk ISNEk ISNFh ISNEh	Inter: ISNEk(60°)(R)-3.02 ±0.30; (L)-3.12 ±0.36; ISNFk(60°)(R)-1.69 ±0.15; (L)-1.64±0.17; ISNEk(180°) (R)-2.15 ±0.42 (L)-2.15 ±0.27; ISNFk(180°)(L)-1.29 ±0.15; (L)-1.25 ±0.13 Coll: ISNEk(60°)(R)-2.86 ±0.30; (L)-2.96 ±0.35; ISNFk(60°)(R)-1.63 ±0.16; (L)-1.16 ±0.16; ISNEk(180°) (R)-2.08 ±0.19 (L)-2.13 ±0.20; ISNFk(180°)(R)-1.19 ±0.14 (L)-1.19 ±0.14	Inter: ISNEh60°)(R)-3.85 ±0.60; (L)-3.88 ±0.59 ISNFh(60°)(R)-2.26 ±0.26 (L)-2.31 ±0.31; ISNEh(180°) (R)-2.87 ±0.62 (L)-2.90 ±0.60; ISNFh(180°)(L)-1.76 ±0.24 (L)-1.80 ±0.30 Coll: ISNEh60°)(R)-3.93 ±0.62; (L)-3.67 ±0.68 ISNFh(60°)(R)-2.36±0.27 (L)-2.33 ±0.34; ISNEh(180°) (R)-3.08 ±0.68;(L)-3.06 ±0.65; ISNFh(180°)(L)-1.90 ±0.28; (L)-1.86 ±0.34;
Yildirim et al. [43] 2019	M-11 (E, Fr)	18.8±1.1	BD GS	GS (47.6 ±6.4kg) BD (140.2 ±30.7kg)	
Venegas-Cardenas et al. [44] 2019	N-20 (E, Jun) M-14 F-6 Gr-8 Fr-12	Gr-16.9±1.6 Fr-15±1.4	SJ CMJ GS (D, EE, EB)	Gr: SJ-33.8 ±4cm CMJ-37.1 ±5.5cm GS(EE)-49.5 ±7.4 GS(EB)-49.3 ±5.9	F: SJ-25.2 ±6.6cm CMJ-27.7 ±6.7cm GS(EE)-36.7 ±8 GS(EB)-35.3 ±8.5

Study, year	Participants		Strength variables	Results	
	number and groups	age (years)			
Acar et al. [45] 2020	M-86 (Fr) Sb-41 Cad-21 Jun-24	Sb-10-14 Cad-15.17 Jun-18-21	LJ GS Su Tbt	Sb; LJ-194.99 ±2.99; GS(R)-28.41 ±20.89; GS(L)-27.04 ±11.33; Su-26.08 ±5.88; tbt-5.22 ±1.81; Cad: LJ-226.17 ±16.93**GS(R)-45.1 ±8.16**; GS(L)-41.43 ±8.65**; Su-32.31 ±5.76**; tbt-7.81 ±1.96**	Jun LJ-242.69 ±19.83** GS(R)-46.73 ±3.15** GS(L)-45.47 ±4.66** Su-37.29 ±3.99** tbt-9.52 ±1.16**
Aksoy et al. [21] 2020	M-39	12.05±1.23	GS SJ VJ LJ Tbt	**SJ: (25.51 ±6.41 to 30.20 ±5.38cm); **VJ (26 .13 ±7.41 to 32.45 ±); **LJ (161.31 ±20.28 to 176.77 ±21.92cm); **GS (R) (21.77 ±7.67 to 28.24 ±9.12kg); **GS (L) (21.82 ±7.55 to 28.31 ±8.97kg); tbt (517.44 ±150.81 to 580.52 ±156.11cm)	
Ozbay & Ulupinar, [46] 2020	M-26 E-13 tE-13 Fr-12 Gr-14	E-20.5 ±2.3 tE-20 ±2.2	Pu Sq Pup ISOsL CMJ GS LJ	Pu*tE-56.61 ±6.33 E-48.77 ±7.17; Sq* tE-1.47 ±0.16kg E-1.33 ±0.11kg CMJ: tE-29.07 ±2.41cm; E-27.52 ±1.80cm; Pup* (0.003) tE-30.77 ±4.95; E-24.92 ±4.31	
Podrihalo et al. [47] 2020	M-36 E-12 A-24	E-23.92 ±2.11 A-24.33 ±1.69	GS	E GS(R)-63.71 ±3.65 GS(L)-63.09 ±3.48	A GS(R)-57.53 ±2.28 GS(L)-56.9 ±2.36
Cieslinski et al. [48] 2021	M-168 Fr-74 Gr-94 Succ-85 Lsucc-83	Succ-20.91 ±2.93 Lsucc-19.93 ±1.87	Pup LJ	Succ Pup-33.7 ±0.99 LJ-251.5 ±2.03cm	Lsucc Pup-26.5 ±0.91 LJ-244.9 ±2.06cm
Tatlici et al. [49] 2021	M-30 (Gr)	21.7±2.6	KEs KFs	KEs-239.57 ±32.5 KFs-13.30 ±24.75	

Legend: N total number of participants, **M** male, **F** female, **VJ** vertical jump, **GS** grip strength, **EE** elbow extended, **EB** elbow bent, **D** dominant, **ND** not dominant, **L** left, **R** right, **Flex** flexion, **Ext** extension, **NPH** non-preferred hand, **PH** preferred hand, **BD** back dynamometry, **LD** leg dynamometry, **LW** light weight, **MW** middle weight, **HW** heavy weight, **LW** light weight, **A** amateur, **E** elite, Succ-succesful, Lsucc-less succesful, Inter-international, **Coll** college, **Nt** national team, **Ns** nonselected, **tE** top elite, **Gr** Greco-Roman, **Fr** freestyle, **Sb** schoolboys, **Cad** cadets, **Jun** juniors, **Sen** seniors, **CMJ** countermovement jump, **SJ** squat jump, **LJ** long jump, **DJ** drop jump, **B** bench, **Sq** squat, **Pu** push-ups, **Su** sit-ups, **Pup** pull-ups, **tbt** throwing ball test, standing medicine ball test, **ISOsL** isometric strength of legs, **ISOKsL** isokinetic strength of legs, **ISOKsE** isokinetic strength of elbow, **ISOKsB** isokinetic strength of back, **ISOKsS** isokinetic strength of shoulder, **KEs** isokinetic knee extensor strength, **KFs** isokinetic knee flexor strength, **ISNEk** isokinetic concentric extension of knee, **ISNFk** isokinetic concentric flexion of knee, **ISNEh** isokinetic concentric extension of hip, **ISNFh** isokinetic concentric flexion of hip, **statistical improvement, *statistical significance between groups

The most monitored variable is hand grip strength using dynamometer [31, 11, 32, 33, 35, 36, 38, 39, 41, 43-45, 21, 46, 47], along with leg dynamometry [32, 35, 36, 38, 39, 41] and back dynamometry [31, 11, 32, 33, 35, 36, 38, 39, 43].

Explosive power of legs consisted of countermovement jump (CMJ) [5,6,11,34,36,42,43,48 6, 11 33, 37, 5, 41, 44, 46], long jump (LJ) [37, 41, 45, 21, 46, 48], squat jump (SJ) [6, 41, 44, 21] and drop jump (DJ) [41]. There were also realized basic motor tests, pull-ups [6, 5, 40, 46, 48], sit-ups [6, 5, 40, 45], push-ups [46], throwing a medicine ball [45, 21], with 1RM squat and bench [6, 11,33, 40], as well as squat only [34].

Isometric strength of legs conducted only one study [46]. In addition, isokinetic strength of knee was conducted overall in 4 studies [23, 34, 42, 49], where one of them realised the mentioned test with concentric type of exercise [42], as well as concentric and excentric strength of elbow, back and shoulder [4].

DISCUSSION

Hand grip strength – dynamometer

Wrestling is a sport with specific movements, where the hand is the only point of physical contact between the athlete and the implement and/or object, hence the functional importance of the hand to sport performance [50, 51]. Also, strength tests usually take part in the evaluation process of each level wrestlers due to one of the major component in order to the wrestling performance [52]. In hand-to-hand combat sports, hand grip strength is important when pushing, pulling, throwing and controlling the opponent [53-55]. In support of the positive relationship between hand grip strength and combat sport performance, a pooled effect size comparison of elite to sub-elite athletes indicates that elite male athletes possess higher hand grip strength in comparison to their sub-elite counterparts [56, 5], as well as clear advantage during the final part of the match [46]. Demirkan et al. [39] observed trivial to moderate non-significant grip strength differences between elite and sub-elite wrestlers, with preferred and non-preferred hand grip, with statistical differences in elite middle and elite heavy weight wrestlers, as well as differences between selected and non-selected wrestlers for national team [34] and experienced and non-experienced wrestlers [21, 47]. In addition, no athletes older than 15 years demonstrated a 10% greater handgrip peak strength, with their preferred hand, compared with the non-preferred one. In contrast, adolescents and adult wrestlers exhibited similar handgrip strength with both hands. However, a higher percentage in peak handgrip strength can be explained by the changes in body height and hand length in developmental years [57]. According to Bayraktar & Koc [41], strength profiles in Greco-Roman and freestyle results are not that different, which is in accordance to Lopez-Gullon et al. [58]. On the other hand, Arslanogly and Demirkan et al. [36, 38] have found that Greco-Roman wrestlers values in strength variables (grip, legs and back) were higher than those of freestyle wrestlers, and Basar et al. [35] found that the styles of wrestling demonstrates different strength demands on the body, so the differences between Greco-Roman and freestyle wrestlers may be due to the different training and competition-related demands. Based on the given results, further studies should be conducted.

Garcia-Pallares et al. [11] and Yildirim et al. [43] have found that the elite wrestlers exhibited non-significant to largely significant greater grip strength capabilities, while Venegas-Cardenas et al. [44] found very poor handgrip results in elite freestylers. The accentuated grip strength differences between wrestlers may be in part attributed to the differences in age, overall strength and training experience [33], as well as the differences in overall strength (i.e. maximum upper and lower body strength) between the elite and sub-elite athletes [59]. In addition, Acar & Ozer [45] found differences in cadet and junior wrestlers. As a result of these findings, these wrestlers differ from each other, not by their characteristic features but their different sport experience (training experiences), which reveals that beginning sport earlier is an important factor for success in sport. According to Baic et al. [60], 10.38 ±2.9 years is the best time to start to train wrestling, since the most of elite wrestlers usually started at that time. In addition, specific isometric actions that will enhance hand grip strength in addition to upper body strength would potentially be a important part of an elite wrestlers training program [61, 62]. Handgrip strength, as a important elements of wrestling performance, declined earlier after match 2, in one-day tournament [31]. These results underline that the recovery time between successive wrestling matches may be inadequate to allow optimal performance during the last two matches, which are the crucial for athletes success, as well as medal-winning matches in the internationals tournaments [63].

A wrestling match consists of a series of dynamic movements of the legs, hips, and back and also involves isometric grasping for maintaining the position [64]. Given that isometric strength may potentially differentiate between successful and less successful athletes [65], this test can provide important information's about strength diagnostics of wrestlers, as well as strong indication of performance dynamics.

Back and leg strength – dynamometer

Greater levels of strengths give elite wrestlers a clear advantage in sustaining the frequent and forceful muscle contraction that are required during wrestling combat techniques [11]. The same authors have also found significant differences in back strength, in elite and amateur wrestler groups. Bayraktar & Koc [41] came to the result that Greco-Roman and freestyle wrestlers showed similar strength features notwithstanding to their styles. Similar study [58] reported alike results. Contrary to this findings, Basar et al. [35]

leg strength ability was found significantly different between the wrestling styles. Also, when back strength was expressed relative to fat-free mass, the lighter weight group demonstrated greater strength compared with the heavier weight group. In addition, leg strength, relative to lean body mass, was greater in the heavy weight Greco-Roman wrestlers compared with the light and middle weight wrestlers [35].

Demirkan et al. [32] highlighted that elite wrestlers isometric back power is 7-20% higher than amateurs, which is, according to Pallares et al. [33], a significant number. In addition, Garcia-Pallares et al. [11] found significant differences between light weight and middle weight, compared to amateur wrestlers, but without significant difference between light weight and middle weight category. These results are similar to previously reported studies [66, 67, 11] where greater strength and muscle power levels differ between successful and less successful wrestlers. Differences in these results could be related to qualitative upper body and lower body musculature differences, as well as the fact that neural activation patterns and twitch tension per muscle mass under maximal and submaximal concentric actions were also diminished in amateur compared with elite wrestlers [68]. Additional literature studies [69, 70] have also shown that elite and amateur wrestlers have similar characteristics, but there is only significant difference in the years of training experience. Barbas et al. [31] have found that one day wrestling competition imposes significant physiological demands on wrestlers that may adversely affect their performance and inflammatory status, especially during later stages of competition. Likewise, they suggested that the upper body strength, as well as performance of bearhug test, may be more susceptible to decline during the course of a 1-day wrestling tournament than those of the lower body musculature as previously shown [63]. Arslanogly [38] measured back and leg dynamometry in young Greco-Roman wrestlers where they showed higher values than freestyle wrestlers [36]. Yildirim et al. [43] found significant increases in back strength in elite wrestlers, while Sapina et al. [71] gave contrary results, since their sample consisted of children. On examination of the literature, these results may suggest that years of training experience is one of the most critical factors for achieving success in wrestling. The results of this study indicate training background may improve the features such as the level of wrestling skills, technical, tactical, and self-confidence. This gives elite wrestlers a clear advantage during wrestling championships compared with amateurs [39].

1RM back and squat

Wrestling match consists of a series of dynamic movements of the legs, hips and back and also involves isometric grasping for position maintenance. Also, lower body strength is important for freestyle wrestling [72]. According to McGuigan et al. [64], isometric testing provides good indication of an athletes dynamics performance during 1RM testing. Although 1RM results in both squat and bench are different, there should be taking in consideration the elite-amateur comparison [33], different style [6] as well as only elite weight categories [34, 40] and gender, where Zi-Hong et al. [34] participants were female, the maturation and experience of these athletes are playing important role. In addition, the differences in this test was observed between males Iranian [73] and Japanese [74] freestyle wrestlers, where Japanese wrestlers seems to have slightly higher results in most weight classes [74]. Maximum strength appears to be a major factor influencing performance in a variety of different sports [75], as well as absolute strength and power are an important component of wrestling [63, 61]. On the other hand, the athletes are in one point reaching sufficient physical maturity in the elite level, which depends on how early wrestler starts to train in the suitability of the conditions put forward by the basic motoric features during development process [38].

Explosive strength of legs

Vertical jump test is a simple and reliable test that can provide useful information about power and performance of athletes [76]. Jumping heights results (squat jump SJ; countermovement jump CMJ; drop jump DJ) in Bayraktar & Hoc [41] showed no differences between Greco-Roman and freestyle wrestlers, while Venegas-Cardenas et al. [44] results indicate that wrestlers are below average of high-performance athlete in CMJ and SJ, which is in accordance with Weineck [77]. In opposite of these results, Qankqya [78] reported higher values in CMJ and LJ (long jump) in regard to elite wrestlers by Ramirez-Velez et al. [37]. Baić et al. [79] and Starosta et al. [6] also compared wrestling styles and reported higher explosive strength, quantified via CMJ, for the freestyle

wrestlers. Authors attributed this difference to the greater complexity of freestyle wrestling in terms of using both legs, compared to the passive wrestling activity pattern that characterizes the classical style. In contrast, Maria Lopez-Gullon et al. [58] revealed no significant differences in CMJ height and power between styles across different weight classes. This difference seems to be due to the particular fitness features of wrestlers, as well as wrestling school differences [6]. Significant differences also observed Garcia-Pallares et al. [11] in three elite groups (heavy-weight, middle-weight and light-weight), compared to the amateur groups, while Ozbay et al. [46] found significant differences between elite and top elite wrestlers. In addition, some authors have also found differences between successful and less successful wrestlers [33], as well as differences in styles [6]. Many other studies [80, 2, 58, 39, 81] confirmed the those differences. In addition, neuromuscular performance differences will give wrestlers a clear advantage during the most frequently used techniques or moves. This is mainly attributed to the fact that elite wrestlers have higher fat-free mass levels and therefore total muscle mass that can generate force compared with amateur wrestlers [33]. As far as one year follow-up measurements, Aksoy et al. [21] 12 and 13 years old participants LJ results was similar to Aslan et al. [82] 12 year old wrestlers. Since there is a lack of follow-up studies, the future ones are required.

Basic motor tests

It is already proved that next factor in the hierarchy of success is strength. Several studies reported that high strength is the key factor leading to performance success in wrestling. In addition, the ability to produce repetitive power actions is a key factor for the wrestlers to stay in combat despite the fatigue in the final parts of the match [83]. According to some authors [84, 5] successful wrestlers performed approximately 29% more pull-ups and push-ups than less successful ones, with statistical significance [48]. Also, there were found differences between top-elite and elite wrestlers [46], as well as in different styles [6]. Acar & Ozer [45], as well as Nikooie et al. [5], showed lower results in sit-up test, which was in accordance to Aslan et al. [85], where successful overcome non-successful ones. Furthermore, Acar et al. [45] showed higher results in throwing a medicine ball, relative to Ozer et al. [86], while the opposite results have found also by Aslan et al. [85]. Although Aksoy et al. [21] did not showed statistical significance, only improvement happened, the results may be insignificant due to the fact that trainings are in the form of pulling the most of the time, so it could be recommended to include pushing workouts in addition to pulling trainings as well. In addition, several types of research have done physical fitness in wrestlers, but the most dominant factor is muscle strength [87].

Isometric and isokinetic strength

Wrestling is a sport that requires strong muscular strength of upper, as well as lower body [88], which is associated with top wrestling performance [89]. Differences in isometric strength of legs in top-elite and elite wrestlers have found Ozbay et al. [46], which is in accordance with Galcia-Pallares et al. [11, 33], where they have found similar differences in isometric strength between elite an amateur wrestlers. In addition, using binary logistic regression analyses, they indicated that isometric strength, along with training experience, fat-free mass and 1RM strength predict 86.8% of the probability of being in the elite group. Zi-Hong et al. [34] have found that isokinetic strength were not significantly different between weight categories, but gradually increased values were observed, while Yoon [23] have found differences in isokinetic knee strength in Korean and Japanese female wrestles. Freestyle Japanese wrestlers [42] also showed differences in isokinetic strength, since the profiles are international and collegiate levels. These results are not in accordance with Cisar et al. [90], where high level high-school wrestlers showed greater isokinetic knee extension and flexion than their average level counterparts. The possible explanation of differences could be the different performances between mentioned levels of wrestlers, so further investigations is needed.

Limitations

Due to the range of different wrestlers profiles and protocols, as well as diversity in competition rang and categories, the authors cannot with certainty determine an optimal wrestlers profile, which could be main limitation. Another limitation can be attributed to the fact that author did not have complete access to all databases, so the authors decided to summarize all studies under the same analysis set.

CONCLUSIONS

The conclusion drawn from the above facts would be that, based on the identified relevant literature, the most commonly used test to assess different types of strength in wrestlers are handgrip strength, isometric and isokinetic strength, 1RM bench and squat, as well as explosive strength of legs tests.

It is hoped that the physical characteristics and profiles of the wrestlers are presented in this review will serve as an ergonomic framework to prepare athletes for the physiological demands of competition. In addition, more extensive research is warranted in these areas to permit population specific training recommendations.

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