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Balance Assessment with Handstand in Artistic Gymnastics A Systematic Review

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Abstract: Gymnastics is an Olympic sport that requires long hours of training from a young age. Balance along with control of the body's center of gravity is one of the key elements necessary to produce superior athletic performance and one of the most basic parameters in gymnastics playing an important role in the successful execution of sports skills as well as in the prevention of injuries.It is a combination of innate sense and development of physical and mental training.The method used for the implementation of this study was a systematic review of literature references to collect and process all information on the assessment of balance in the sport of gymnastics. Based on inclusion data (studies from 1980 to 2022, full text published in English, the study involved male and female gymnasts who were assessed in dynamic balance with the handstand exercise. After analyzing the results, it is concluded that the use of handstand is an essential skill for the assessment of dynamic balance.

Keywords: Artistic gymnastics, balance, evaluation, gymnasts, handstand, posture

1. Introduction

Balance plays an important role in the successful performance of complex acrobatic elements (Panjan & Sarabon, 2010), particularly in gymnastics, where even a minimal distortion affects the final score (Aleksić-Veljković, Madić, Veličković, Herodek, Popović, 2014), as well as in the prediction of sport injury (Sabin, Ebersole, Martindale, Price & Broglio, 2010). Further, the development of balance allows almost perfect stability, even under extreme conditions (Atilgan, Akin, Alpkaya & Pinar, 2012). Postural balance contributes to the optimization of motor performance in a number of athletic disciplines (Hrysomallis, 2007). Thereare different methods as well as different balance assessment exercises. There are elements that require balancing on hands, so this ability depends on the efficiency of the element execution (Hars, Holvoet, Gillet, Barbier & Lepoutr, 2005). Handstandis one of the most basic exercises performed on the various apparatuses, such as floor exercises, balance beam, still rings, e.t.c. either statically or dynamically (after swinging from the support).Dynamic balance refers to gymnast's ability to perform regulatory movements to maintain a stable center of gravity during exercise (Butler et al., 2012). Although there are systematic reviews on balance in different sports, there have been no corresponding studies on dynamic balance in artistic gymnastics. The purpose of this systematic review was to gather and process all information regarding the use of the handstand as a balance assessment skill in the sport of artistic gymnastics (AG).

Methods

This systematic review is based on studies that were found through computerized searches of Pub Medκαι Sport Discus from 1980 to 2022and mention handstand as a balance assessment skill in artistic gymnastics.

Search Strategy

The search was done by using the following keywords: gymnastics, male and female gymnasts, balance, dynamic balance, static balance, stability, posture. The structure and writing of this study were based on the model of Kable et al. (2012).Only the studies that met the following criteria were included: artistic gymnastics, competitive artistic gymnastics, gymnasts, male, female, balance, static balance, dynamic balance, stability, posture, and being published in English language.Studies were excluded if the PEDro scale was lower than five (Table 1), or handstand skill was not described in detail. The reviewers conducted the literature review independently, based on inclusion and exclusion criteria. In total, 13 studies met the inclusion criteria for review (Figure 1).

Figure 1 is About Here

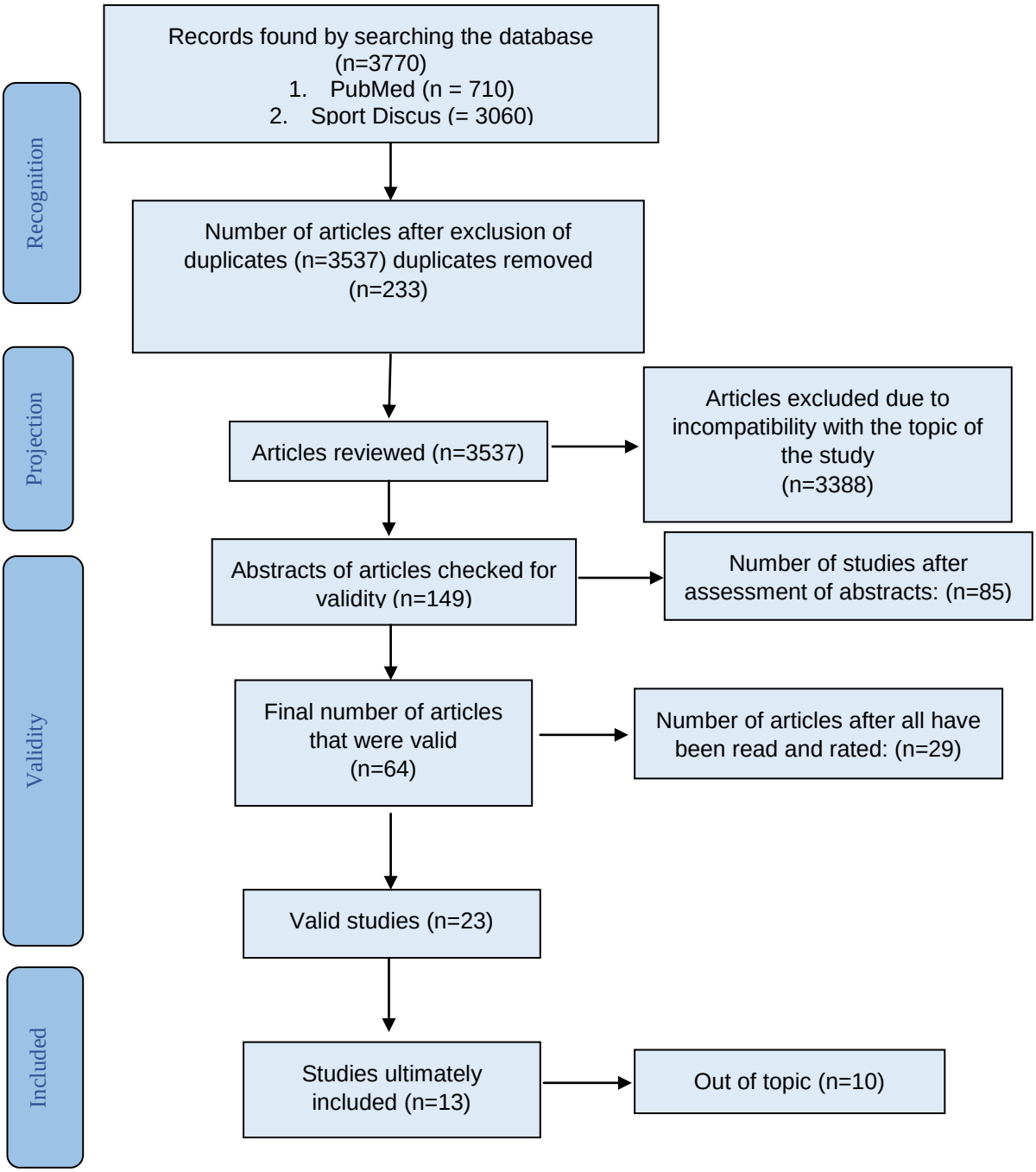

Figure 1: A flow chart illustrating the different phases of the search and study selection

Relevancy review of retrieved articles

The assessment of the relevance of the articles found was done with the three-step process according to the Bettany-Saltikov (2010) model based on the inclusion and exclusion criteria set in the specific study. First, all the titles of the collected articles were evaluated. Initially, articles - studies that were not relevant to the purpose of the present study were excluded. Therefore, if the title of the article did not provide sufficient information's, then further examination was done to assess its relevance.

Quality of included studies

With reference to the total number of studies included in this thesis and based on the grades of each study based on the PEDro scale, the overall evaluation score of these studies was determined. Maher et al. (2003) report that the maximum score that can be given to each study is between 8-11. Please note that if the awarded score is between 0–3 points, this study will be classified as "poor" quality, 4–5 points as "fair" quality, 6–8 points as "good" quality and 9–10 points as "excellent". Of all the included studies in this systematic review, 2 studies showed fair quality, and 11 studies showed good quality.

Table 1: Pedro scale of included studies

	Criteria											
Study	1	2	3	4	5	6	7	8	9	10	11	Score
Wyatt et al(2018)	N	-	O	N	O	-	-	N	-	N	N	5
Croix etal(2010)	N	-	X	N	X	X	X	N	N	N	N	6
Aleksić-Veljković et al (2014)	N	X	X	N	X	X	X	N	N	N	N	6
Cian et al (2015)	N	X	X	N	X	X	X	N	N	X	N	5
Asseman et al (2003)	N	X	X	N	N	-	-	N	N	N	N	7
Gautier et al(2009)	N	X	X	N	X	-	-	N	N	N	N	6
Gautier et al(2007)	N	N	X	N	X	-	X	N	N	N	N	7
Kochanowicza et al (2018)	N	X	X	N	X	X	X	N	N	N	N	6
Omorczyk et al (2019)	N	X	X	N	X	X	X	N	N	N	N	6
Croix et al,(2010)	N	N	X	N	X	X	X	N	N	N	N	7
Kochanowicz et al(2015)	N	X	N	N	X	X	X	N	N	N	N	7
Puszczalowska-lizis et al (2019)	N	X	N	N	-	-	-	N	N	N	N	7
Omorczyk et al (2018)	N	X	X	N	-	-	-	N	N	N	N	6

1- eligibility criteria were specified, 2- subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received), 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 therapists who administered the therapy, 7- there was blinding of all assessors who measured at least one key outcome, 8- measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups, 9- all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat", 10- the results of 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

Results

Twenty-three studies were identified and on the basis of inclusion criteria 10 studies were excluded and only 13 studies were included in this study (table 2).

Table 2: Review of included studies

Author Year of publication	*Sample - Subjects*			*Intervention program*	*Skill Assessment*	*Results*
	sample / groups	*Age (year)*	*Training experience*			
Wyatt et al (2018)	12 female gymnasts	9-15	International level	20 handstands (max 15 sec each) 3 assessments	Handstand i) DSI, ii) ANTPOSTCP, iii) LUMSI, Ground reaction & CP (from upright position & from handstand)	***DPSI*** (initial) 17.05 ±12.87 (middle) 22.74 ± 13.95(final)30.71 ± 19.55 **APCoP (mm)** (initial) 76.71±19.01 (middle) 62.41±13.80(final) 61.80±17.87 **DLPSI** (initial)12.77 ±6.21 (middle)13.14 ± 8.44(final)12.22 ± 5.23 **Posture** (initial)−1.9 ± 5.9 (middle) −4.6 ± 5.9(final)−2.0 ± 6.2
Croix G. et al (2010)	17 male gymnasts 2 groups 1st :6 female / 2 male 2nd:7 female / 2 male	1st group: experienced 22.0 ±3.3 2nd group: non experienced 20.2 ± 1.6	1st: 15.6 ± 2.7 2nd: 8.7± 2.3	Handstand on 4 conditions Vfirm; Vfoam; NVfirm; NVfoam	Handstand on a horizontal stabilometric platform	Failure to perform handstand with close eyes non-experience Smaller sway range of experts' gymnasts with eyes closed Greater sway with closed eyes
Aleksić-Veljković et al (2014)	46 female gymnasts 1stgroup: n=22 2ndgroup: n=26	1st group: 9.0±1.1 2nd group: 12.1 ± 0.6		duration of each trial 10sec	Static balance assessment (scale, handstand. & handstand in a sideways position)	Score 1st group: 9.00 ± 1.15 2nd group: 8.45 ± 1.21
Cian et al (2015)	26 maleAG 1st group: 12 2nd group: 14	1st group: 20-35 2nd group: 15-28		2 conditions 5 trials per condition Minimum downtime 5 sec	Handstand on a special platform wearing two kinds of uniform (Placebo suit, bioceramic suit)	*Duration:*bioceramic suit (535.6 mm) placebo suit (569.5 mm), t = 1.816, p = .0924, Range (mm): bioceramic(51.91 mm) placebo suit 56.17mm) t= 2.278, p = .0403, Velocity: bioceramic (81.73 placebo suit (83.67), (t = 0.68, p = .506)
Asseman et al (2004)	15 gymnasts	21.6 ± 3.9	International level	SPOE for 32 sec 3 condition * 5 trials	1stcondition: twolegs 2ndcondition: one leg, 3rd condition: Handstand	Better score on handstand
Gautier et al (2009)	16 male & female gymnasts / 2 groups		1st group: experienced 2nd group: non-experienced	STSonhandstand 3 conditions (0,2, 0,4,0,6 Hz)	Handstand.	Ability to execute from both groups Less number of experienced falls
Gautier et al (2007)	10 male gymnasts	*18-25*		Handstand 4 conditions: OE, CE, PERCENVV 3 trials per condition	Handstand	Vision: 47,56% responsible for maintaining balancein handstand. ´ regional 12.49%, central 20.98%
Kochanowicza et al (2018)	15teennager 11 adults	13.9 ± 0.7 23 ± 3	International level	3 trials on handstand / each 10sec	Body posture muscle activity in the EMG on a special platform	Better adult postural control performance Higher wrist activity in both groups. Different EMG
Omorczyk et al (2019)	20 male gymnasts	21.10 ± 3.80	15.25±3.60	3 trials - 30sec 1η: BSSP,2η : CE; 3η: Handstand	Assessing the relationship between attitude stability and psychological factors	No significant correlation of stability and psychological factor in the standing position or even with CE in contrast with handstand due to level difficulty and loss of self-confidence
Croix et al, (2010)	8 female gymnasts	19.9 ± 1.8		Handstand 10sec 4 conditions 1ηOE; 2ηCE; 3ηOEC; 4ηCEC	Handstand	**Sway rangeMedial-lateral axis:** 1η26,66 ± 3,29; 2η 8.32±7.17 3η 22,46 ± 1,43; 4η27.78 ± 3.81 **Anterior-posterior axis:** 1η4.97 ± 6.32; 2η 58.02 ± 8.15 3η42.09 ± 5.97; 4η8.37 ±7.16 **Velocity displacement**

						1η 75.58 ± 6.91; 2η 103.92± 11.51 3η 86.16 ± 8.80; 4η78.55 ± 7.05
Kochanowicz et al (2015)	20 έφηβοι 12 experienced	1st group: 11-12 2nd group: 18-26	International level	Maintaining in handstand.	Handstand	RLofCP 1stgrouplowerthan 2ndgroup (111,74 ±17,30 &72,22 ±32,98 cm) d= 39,52cm MS onX axis 1st group: 1.75 ±0.60 cm; 2η 0.97 ±0.46 cmd= 0,78cm Y axis 1st: 3.03 ± 0.44 cm; 2nd: 2.05 ± 0.77 cmd= 1cm
Puszczalowska-lizis et al (2019)	20 male gymnasts	21.10 ± 3.8	15.25 ± 3.60	3 trials, duration 30sec	Evaluation and comparison of stability values in 3 different conditions 1st measurement: standing stability measurement 2η : CE 3η : handstand	**SA (conditions)** 1η: 149.95 ± 118.87; 2η: 229.40 ± 165.64; 3η :2261.55 ± 1159.1 **RLSK**1η:219.80 ± 43.71; 2η:319.70 ±115.19 3η 1518.20±352.85 MV: 1η: 7.33 ± 1.4; 2η 10.65 ± 3.84; 3η 50.61 ± 11.76 MF1η 0.69 ± 0.26; 2η 0.76 ± 0.27; 3η 1.22 ± 0.25
Omorczyk et al (2018)	46 gymnasts 1st group: teenagers 2nd group: adults	*1st group:* 15.9 ± 0.8 2nd group: 22.7 ± 4.6	*1st group:*10.30 ± 0,80 2nd group: 16.70 ± 3.60	*2 trials * 30sec* *1η: standing position* *2η: handstand.*	Comparison of balance from a standing position and handstand in relation to the level of the athletes	**Uprightposition**Στατοκινησιόγραμμα 1η ομ:258.0 ± 49.6; 2η: 212.7 ± 29.6 ANTPOSTA 1st group: 163.0 ± 39.0; 2ηομ: 129.6 ± 23.3 MLA 1sr group: 164.5 ± 28.2; 2nd group: 140.8 ± 21.6 MDIS1st group: 2.6 ± 1.5; 2nd group: 1.7 ± 0.9 **SA**: 1st group: 222.7 ± 156.7; 2nd group: 117.0 ± 61.1 **MF: 1st group**: 0.6 ± 0.2; 2nd group: 0.8 ± 0.3 **SK:** 1η: 1714.6 ± 548.0; 2η: 1435.5 ± 388.9 **ANTA:** 1st: 1435.5 ± 524.9; 2nd: 1199.8 ± 362.5 MLA: 1st: 644.1 ± 222.5; 2nd: 562.9 ± 149.8 MDIS 1st: 8.5 ± 2.9; 2nd: 6.6 ± 2.1 SA 1st: 3994.9 ± 2612.9; 2nd: 2480.8 ± 1117.0 MF 1η : 1.1 ± 0.3; 2η : 1.2 ± 0,.3

Abbreviations: DSI: Dynamicstabilityindex, **ANTPIOSTCP:** anteroposterior Center of Pressure, **LUMSI:** Lumbopelvic stability index, **CP**: Centre of pressure, **RL**: route's length, **MS**: maximum sway, **d**: difference, **SA:**sway area, **PLSK:** Path length static kinematics, **Vfirm:** open eyes stable surface, **Vfoam**: open eyes foam surface, **Nvfirm**: closed eyes stable surface, **Nvfoam**: closed eyes foam surface, **BSSP**: body stability in standing position, **SP**: stable position, **PERCENVV**: peripheral and central vision variables, **C:** contact, **ANTPOSTA:** anterior-posterior axis, **MLA**: mediolateral axis, **MDIS:** Mean displacement, **SA:** Swing area, **MF:** Mean frequency, **SW:**sway target, **EMG:** Electromyography, **DPSI**: dynamic postural stability index, **APCoP**: anterior-posterior centre of pressure, **DLPSI**: dynamic lumbo-pelvic stability index, **AG**: Artistic Gymnasts, **OE:** Open eyes, **CE:** closed eyes, **STS:** Sway target sequence, **SK**: static kinesiogram

A total of 271 gymnasts participated in these studies. Of these studies, three refer to a sample of 71 female athletes, 5 studies to a sample of 80 male athletes, while 6 studies do not mention the gender of the participating athletes. Four studies refer to the evaluation of international level athletes, while the duration of vertical position (pause) ranges from 5 to 30 seconds. The largest number of participants was 46 while the smallest was 8. Three studies had a female sample, 8 studies had a male sample and 2 studies had a mixed sample. The oldest participant was 28 years old and the youngest 9. The oldest training age in AG was 16.70 ± 3.60 while the youngest was 8.7 ± 2.3.The most commonly measured exercise to assess balance was handstand compared to standing. The tests were performed on special force platforms, of which 3 studies had the two platform Postugraph (CQ Electronic system) and 3 the horizontal stabilometric platform (QFP system), while other types were also mentioned (Mondo covered

force plate, Triangular force plate TME, model CMC 301, EMG signal force platform, Accu Gait force plate).The evaluation conditions were four, (stable and foam surface, open and closed eyes)

Discussion

Based on the review of the studies used regarding balance, which is a key parameter in gymnastics, and more specifically examining the handstand, it seems that it is a difficult task that requires a high degree of muscular strength and endurance to hold all of its weight body in the inverted position. As shown by the results of the studies, it is an ability that depends on proprioceptive, vestibular and visual sensors since the athletes just lost some senses (e.g. test with closed eyes) their performance decreased. Maintaining balance in an inverted position is difficult due to: 1) a smaller base of support, 2) a higher center of mass than in an upright position, and 3) less strength of the wrist joints compared to the ankles. Training age plays an important role because artistic gymnasts undergo continuous training learning basic skills and thus gain a greater sense of balance. In all studies conducted, more experienced gymnasts performed better in handstand than less experienced athletes.

Conclusions

The handstand is one of the most basic exercises of artistic gymnastics for all age stages and for this reason it is a parameter for evaluating the balance of the participants in this sport.The evaluation method and conditions vary depending on the purpose of the study, while the duration of the vertical stop is related to the training experience and the level of the athletes.

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