

# COMPARISON OF THE TRADITIONAL TRAINING METHOD TO TEACH HANDSTAND AND TRAINING THROUGH A RESEARCHER-MADE DEVICE AND THEIR IMPACT ON THE HANDSTAND DURATION, PAIN AND QUALITY OF PERFORMANCE IN 8-10-YEAR-OLD BEGINNER GYMNAST GIRLS

**Solmaz Nabizadeh Morsalfard, Mohamed Hosein Nasermeli and Behnaz Ganji Namin**

Faculty of Physical Education & Sport Sciences. Islamic Azad University, Karaj, Alborz, Iran.

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## **Abstract**

*This research was conducted with the aim of comparing traditional handstand training and handstand training using a researcher-made device among beginner gymnast girls aged 8 to 10 years. To achieve this, 30 qualified female gymnasts were purposefully and conveniently selected and randomly assigned to two groups: one receiving educational assistance with the researcher-made device (n=15) and the other using the traditional method (n=15). Over a span of eight weeks, handstand movements were taught, with one group following traditional methods and the other utilizing the researcher-made device. Upon completion of the training period, various measurements were taken, including the duration of balance maintenance, balance quality as judged by experts, the range of motion in the wrist, elbow, shoulder, and ankle joints, and the assessment of pain in the wrist, elbow, shoulder, and lower back areas. Data were analyzed using independent t-tests, MANOVA, and the Mann-Whitney test, with a significance level set at  $P \geq 0.05$ , and the analysis was conducted using SPSS 22 software. The results demonstrated that the use of the researcher-made balance training device led to a significant improvement in balance quality from the perspective of judges, as well as a notable reduction in pain in the shoulder, back, and wrist areas compared to the traditional training method. Additionally, there were no significant differences between the traditional method and the use of the device when considering factors such as balance performance quality as measured by deviation from the vertical line in various body joints, the duration of balance maintenance, the range of motion in the wrist, elbow, shoulder, ankle, and pain in the elbow and knee.*

**Keywords:** Handstand, aiding device, gymnastics, training quality, pain.

## INTRODUCTION

As a mother sport, gymnastics has taken root in all parts of the world due to its unique characteristics and charms, attracting many enthusiasts' attention.

'Handstand' is one of the principal gymnastic skills, playing an essential role in this sport; however, sometimes, due to the lack of proper training and attention by coaches, as well as physical and biomechanical incompetence in this movement, other gymnastics skills are also affected. In this skill, keeping the body straight and stretched along with the contraction of the abdominal and pelvic muscles and knowing the rules of balance and orientation are of utmost importance (Razavi, 2004). Transitioning from an upright standing posture to an inverted stance, or 'handstand balance', relies initially on large changes in body positioning and once inverted, on subtle changes of hand pressure and limb actions to control posture during the stabilizing period. The performer is required to transition through a period of instability to reach a balanced posture. The interplay between the numerous neurophysiological and biomechanical control processes is anticipated to be vital to the duration of handstand balance and has the potential to differentiate more and less successful handstand performance (Wyatt HE et al., 2021)

Besides its musculoskeletal benefits, practicing handstand has some positive physiological consequences. In a case study, researchers examined a Chinese man who practiced handstands (balance) for 40 years and found that this movement can strengthen cerebral vessels and delay the signs of aging (Liu et al., 2020).

It takes a lot of time and skill to perform many gymnastics movements. Elite gymnasts usually practice between 20 and 40 hours a week (Ghasempour, 2008), and repeated movements are often essential to mastering different skills in the field. Unlike many sports, movements and skills are practiced and repeated in gymnastics. Due to these repeated pressures or the wrong implementation of severe twists and blows during landing, the likelihood of acute and overuse injuries increases.

An investigation into injury rate during 2014-2019 among women's gymnastics athletes in the National Collegiate Athletic Association (NCAA) shows that the overall injury rate was 8.00 per 1000 athlete exposures; injury incidence was greater in competitions than in practices, though practice injury rates increased from 2015–2016 through 2018–2019. Findings also suggest that the etiologies of overuse injuries and inflammatory conditions as well as the biomechanical aspects of concussions warrant further attention (Chandran et al 2021). Researchers showed that most upper limb injuries in female gymnasts occur in the wrist and continue with elbow injuries. This type of injury has been seen more in female gymnasts aged 10 to 14 (Webb and Retting, 2008). Filming a person standing on their hands for five seconds showed that the most changes were in the wrist, followed by the shoulder, hip joint, knee, and elbow. Also, the most angular changes were observed in the wrist area. Therefore, the wrist plays the most crucial role in maintaining the center of gravity on the support (Mohammadi et al., 2011). DiFiori et al (2006) emphasized that 25% of non-professional gymnasts had severe or advanced distal radial physical

stress injury (injury due to weight pressure) in the wrist (DiFiori et al., 2006). Upper and lower limb injury prevalences have been reported at 32.2% and 58%, respectively (Jafari and Bam, 2001). In their review research, Caine and Nassar (2005) investigated gymnastics injuries. The results showed that injuries differ according to the gender of individuals. Most injuries were reported in the ankle joints and the lower back area at the advanced level (Caine and Nassar, 2005).

Among the causes of injuries, the type of equipment (ground movements) (56.8%), incorrect technique, and not using educational aids (36.4%) were the most common causes of injuries (Jafari and Bam, 2001). In this regard, appropriate training aids, safety mattresses, and other requirements can be helpful. Training aids can be used in more desirable learning techniques and the source of potential mistakes in skills implementation should be found. Therefore, with the aim of reducing sports injuries and promoting athletes' health during championships, it is recommended to use training facilities, and appropriate safety equipment (Jafari et al., 2011).

Training tools and devices are consistently employed to enhance the training of sports skills. Some of these tools not only promote safety but also facilitate the training process (Shojauddin, 2003). According to the outcomes of utilizing training aids such as modeling and display, which enhance the effectiveness of learning, there is a need to encourage educators and instructors to adopt more effective teaching methods and training aids instead of conventional approaches (Maleki et al., 2012). Additionally, biomechanical aspects of gymnastics sports equipment were investigated through videography,

highlighting the significance of equipment in evaluating, analyzing, and measuring dynamic and kinematic structures within the field of gymnastics (POTOP, 2013).

Unfortunately, studies about specific movements in gymnastics, including handstands, are limited. Handstand is one of the basic movements of this sport, and there is no training aid to increase training efficacy and decrease pain or injury risks. It motivated the researchers to build a device to facilitate training of this skill. The absence of specialized studies addressing specific movements in gymnastics, including handstands (Woods et al., 2002), coupled with the elevated incidence of injuries associated with this manoeuvre, and the inadequacy of appropriate training aids for its instruction, have served as the foundational motivation for undertaking this research. The primary objective of this study is to compare the effectiveness of traditional handstand training methods with a novel researcher-developed device in relation to the movement quality, balance duration, range of motion, and the occurrence of pain (specifically in the wrist, elbow, shoulder, and ankle) among beginner gymnast girls aged 8-10 years.

## METHODS

30 physically and mentally healthy, relatively less skilled gymnast girls, aged 8 to 10 years ( $8.8 \pm 0.8$  years,  $131.7 \pm 15.6$  cm,  $26.9 \pm 7.7$  kg) elected to participate in this study. They were randomly placed in two groups: one training with a researcher-made device (1:  $n=15$ ), and another as a control group, using the traditional training method (2:  $n=15$ ). The subjects practiced handstand balance for at least three months, three days a week.

The semi-experimental method was employed using a post-test design with the control group. An open call for participation was made by reaching out to a gymnastics academy located in western Tehran, and an unrestricted number of questionnaires were distributed among relatively less-skilled gymnasts. To ensure the participants' health status, all volunteers were examined by a physician. Consent forms for participation in the research were provided to the parents, and subjects were included based on predefined inclusion criteria.

The duration of maintaining handstand balance, the quality of performance, and the range of motion and pain were measured after the intervention.

The duration of maintaining handstand balance was measured using a stopwatch. The examiners stopped the stopwatch upon observing any swinging or movement in the gymnast's body, and recorded the time during which the balance was maintained.

The performance quality of the handstand was evaluated using both the score of the judges and the deviation of the joints from the vertical line.

Opening the hands less than or more than shoulder width, creating cervical hyperlordosis in the head which can lead to lumbar hyperlordosis, bending and spreading the legs apart, failing to transfer weight onto the hands, and shifting the shoulders forward were the factors that affect the quality of the handstand movement according to international rules.

Deviation from the vertical line: The analysis was conducted using motion capture software, Cortex 6.0.0.1645, and Kinovea 0.9.4. Cortex is a motion analysis software tool designed to manage all aspects of motion capture within a single program, encompassing tasks such as initial setup, calibration, tracking, and post-

processing. On the other hand, Kinovea is a free software application used for video analysis, comparison, and assessment in sports and training context. It is particularly suitable for physical education teachers and coaches (Nor M, et al, 2018).

The range of motion for wrist hyperextension, shoulder internal rotation and flexion, hip flexion with a bent knee, knee extension, and ankle dorsiflexion was measured using a goniometer according to the Kendall method (2005).

Visual Analogue Scale (VAS) was employed to gauge pain intensity. Observational evaluation indices for the handstand posture were established after verifying their validity, reliability, and the hierarchy of technical issues (Kojima et al., 2021). The measurement criterion consists of a 10cm long horizontal strip graded from 0 (no pain), 1-3 (mild pain), 4-7 (moderate pain), and 8-10 (severe pain). This scale has high reliability and reproducibility (70 / 69) with a reliability coefficient of ICC=0.91. Subjects refrained from using anti-inflammatories and painkillers 72 hours prior to the pain evaluation test, and they were instructed on how to use the measurement criteria.

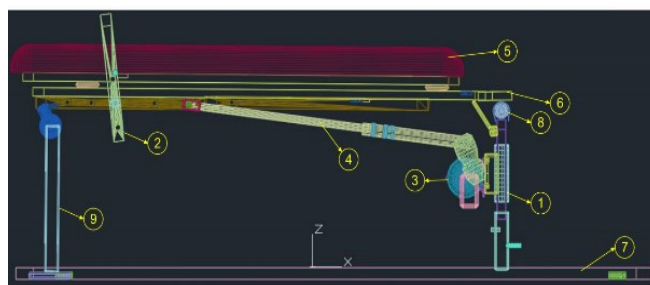
Intervention: Traditional handstand method (control group): A progressive teaching model for introducing the handstand to beginner gymnasts was employed, drawing upon theoretical and contemporary skill training methods found in scientific and textbook literature. This approach was realized by reviewing pertinent research studies available via Medline, contemporary gymnastic textbooks, coaching manuals, as well as the author's personal knowledge and experience. The model proposed outlines four distinct stages in the progression of handstand development, featuring a

distinctive strategy aimed at enhancing the gymnast's proprioceptive and kinesthetic awareness for maintaining balance (Uzunov, 2008).

Researcher-made device method: The transition from an upright standing posture to an inverted stance, commonly referred to as 'handstand balance,' initially relies on significant changes in body positioning. Once inverted, fine adjustments in hand pressure and limb movements are essential for posture control during the stabilization phase. Special emphasis has been placed on

understanding the mechanics in the anterior-posterior (AP) or sagittal plane (Wyatt HE et al., 2021).

Building upon this understanding, a balance training aid was developed with the specific goal of managing movement in both the sagittal and frontal planes. The objective behind designing this tool was to incrementally expand the range of balance, up to 15 degrees, in accordance with the gymnast's proficiency level. As depicted in the original design in Figure 1, this device comprises several components, including:



*Figure 1.* 3D image of the device, side view: 1. The adjustable base of the device; 2. A holding bar to prevent the gymnast from falling during the peak phase; 3. An electric motor to move the jack and lift the gymnast's body along with the bottom plate; 4. A pneumatic jack - to transfer the power of the engine to lift the bottom plate; 5. Foam on the bottom plate - to prevent injuries and provide comfort; 6. The metal frame of the lower plate - to keep in place; 7. The lower metal frame of the device for stability; 8. A hinge - for joint movement of the bottom plate; 9. A support base - to maintain the bottom plate in its original state before and after the movement.

This device comprises two vertical bars positioned on both sides of the gymnastic mat, allowing for height adjustment. These bars are connected at the top by a horizontal bar and a rectangular plate. The rectangular plate serves as the platform for the individual's body, with hands placed on the mat on the floor to initiate the exercise from a horizontal position. A controller, held by the coach, regulates the movement of this rectangular platform.

With each press of the control key, the rectangular plate incrementally moves 15

degrees vertically before coming to a stop. This pause allows for wrist adjustment and subsequent adaptation of other body organs to the new position. Subsequently, the key is pressed again to advance by the next 15 degrees. This process continues until the individual reaches the vertical position, achieving balance.

Additionally, a semicircular horizontal bar is provided in the area where the feet are placed. This bar allows for foot movement and acts as a safety measure, preventing the person from tipping over to the opposite side (see Figure 2).



Figure 2. the handstand training using a researcher-made device.

All data analysis was conducted using SPSS statistics computing program version 22 (SPSS Inc. \_ 1993–2007). Descriptive statistics (Means $\pm$ SD) for all variables were calculated. Next, data were analyzed with Shapiro-Wilk normality tests to ensure normality, and student Independent T-test, MANOVA, and Mann-Whitney tests were used to compare the differences. Differences were considered statistically significant at the  $p \leq 0.05$  levels.

## RESULTS

The average and standard deviation of the research variables, including performance quality based on time (judges' score), handstand stabilization time, pain (in the areas of the wrist, elbow, shoulder, low back, and ankle), range of motion (areas of the wrist, elbow, shoulder, and ankle), and the deviation from the vertical line (in the areas of the elbow, shoulder, knee, thigh, and ankle) are presented in Table1.

Table 1

*The average and standard deviation of the research variables*

Variable	Traditional group Mean $\pm$ SD	Device group Mean $\pm$ SD	Variable	Traditional group Mean $\pm$ SD	Device group Mean $\pm$ SD
Performance quality (judges' score)	4.40 $\pm$ 1.40	7.08 $\pm$ 2.60	Range of motion (degree)		
Handstand stability (seconds)	1.07 $\pm$ 0.60	3.11 $\pm$ 2.90	Wrist	90.20 $\pm$ 5.60	95.80 $\pm$ 8.50
Pain (VAS)			Elbow	173.70 $\pm$ 7.70	173.80 $\pm$ 7.70
Wrist	0.66 $\pm$ 0.89	0.00	Shoulder	167.06 $\pm$ 12.6	166.40 $\pm$ 12.50
Elbow	0.00	0.00	Ankle	154.06 $\pm$ 15.3	152.70 $\pm$ 16.40
Shoulder	1.86 $\pm$ 0.51	0.93 $\pm$ 0.90	Deviation from the vertical line (degree)		
Waist	4.13 $\pm$ 1.60	0.00	Elbow	1.30 $\pm$ 1.10	1.55 $\pm$ 1.70
Ankle	0.00	0.00	Shoulder	2.65 $\pm$ 1.80	2.09 $\pm$ 2.06
			Thigh	6.16 $\pm$ 4.70	4.69 $\pm$ 5.20
			Knee	5.26 $\pm$ 5.10	4.39 $\pm$ 5.20
			Ankle	5.82 $\pm$ 5.40	4.87 $\pm$ 6.80

The results of the Shapiro-Wilk test showed that the data of performance quality and deviation from the vertical line are normally distributed ( $P>0.05$ ). Therefore, independent t-test and MANOVA were used to analyze the data of these variables.

In contrast, the data for time to maintain balance and range of motion are not normally distributed ( $P<0.05$ ); therefore, a non-parametric Mann-Whitney test was used to analyze these data.

The performance quality of the handstand was assessed using both judges' scores and the deviation from the vertical line at various body joints. Consequently, the hypothesis was tested twice: first, based on judges' scores and then based on the degree of deviation from the vertical line.

Based on the results of the independent t-test (Table 2), a significant difference was found in the performance quality of the handstand movement when evaluated from the judges' perspective between the researcher-made device and the traditional method. In other words, the performance quality of the balance movement using the researcher-made device was significantly superior to that achieved through the traditional method.

For a more precise analysis, the MANOVA test was applied, focusing on the deviation from the vertical line. As

indicated in Table 3, when assessing performance quality based on the deviation from the vertical line, there was no significant difference observed between the researcher-made device and the traditional method.

The results of the Mann-Whitney test (Table 4) show no significant difference in balance maintenance time between the researcher-made device and the traditional method.

The results of the Mann-Whitney test (Table 5) show no significant difference in the range of motion in the wrist, elbow, shoulder, and ankle between the researcher-made device and the traditional method; therefore, this hypothesis is also rejected.

The results of the Mann-Whitney test (Table 6) show a significant difference in the pain experienced in the wrist, shoulder, and back regions when comparing the researcher-made device and the traditional method. In other words, the use of the researcher-made device significantly reduced wrist, shoulder, and lower back pain in comparison to the traditional handstand training approach.

However, it is noteworthy that there is no significant difference observed in elbow pain between the researcher-made device and the traditional method

Table 2  
*Independent t-test results for performance quality (judges' score)*

Levine test		t-test		
F	Sig.	T	Df	Sig.
9.950	0.004	-3.570	23.700	0.001
				0.002

Table 3

*Results of MANOVA test for performance quality (deviation from the vertical line)*

Effect	Value	F	Df	Df	Sig.
Intercept	0.702	11.770	5	25	0.000
Group	0.116	0.659	5	25	0.658
Effect	Value	F	Df	Df	Sig.
Intercept	0.702	11.770	5	25	0.000
Group	0.116	0.659	5	25	0.658

Table 4

*Results of the Mann-Whitney test for Balance maintenance time*

U	Z	Sig.
156	1.42	0.163

Table 5

*Mann-Whitney results for a range of motion in wrist, elbow, shoulder, and ankle*

Variable	U	Z	Sig.
Wrist	161.5	1.860	0.101
Elbow	124.0	0.162	0.871
Shoulder	116.5	-0.140	0.889
Ankle	113.0	-0.277	0.800

Table 6

*Mann-Whitney results for wrist, elbow, shoulder and back pain*

Variable	U	Z	Sig.
Wrist	64	-3.03	0.027
Elbow	120	0.00	1.000
Shoulder	49	-2.99	0.004
Waist	0	-5.11	0.000

## DISCUSSION

This research aimed to compare traditional handstand training with handstand training using a researcher-made device in 8-10-year-old beginner gymnast girls, focusing on both the duration and quality of handstand training. The study's findings revealed that when assessing the quality of handstand movement from the judges' perspective, the researcher-made device yielded significantly better results than the traditional handstand training method ( $P=0.002$ ).

However, when using the amount of deviation from the vertical line as the measure of handstand movement quality, no significant difference was observed between the traditional handstand training method and the training aid device.

According to the findings reported by the researchers, the control and regulation of body posture are closely tied to the practice of sports skills, indicating a direct link between the level of physical exercise and one's body posture capabilities. Consequently, the researcher-made device used in this study appears to be better suited



for designing training programs aimed at injury prevention during training rather than for increasing the duration of training sessions.

Additionally, the research demonstrated that the device did not outperform the traditional method in terms of the duration of handstand balance maintenance. It's worth noting that the correct execution of this skill relies on having adequate hand muscle strength to support the entire body weight within the shoulder girdle, particularly on the wrists (Vuillerme et al., 2001; A'boub et al., 2017).

It is worth mentioning that the handstand training device made by researchers was not made to enhance muscle strength, rather, it facilitates controlled movement. Maintaining balance requires the engagement of visual, proprioception sense, and vestibular systems (Vuillerme et al., 2005; Fransson et al., 2004). The better these systems function, the quicker one can learn and demonstrate balance skills. Given that four joints (wrist, elbow, shoulder, and thighs) are involved in maintaining balance, the strategies for achieving balance are more intricate (Asseman et al., 2004).

In this context, the research findings suggest that when handstand training is complemented by a live model and animation, skill acquisition and retention are improved. However, in this study, there was no discernible difference in the learning duration of the handstand between the two groups, likely due to the device's primary purpose, which does not focus on enhancing the abilities of the visual, proprioceptive, and vestibular systems. Consequently, variations in the duration of balance maintenance among beginners may be considered typical (Maleki et al., 2012).

The findings concerning the range of motion revealed that this variable in the wrist, elbow, shoulder, and ankle areas remained unaffected by the use of the teaching aid device. It's worth noting that alterations in the connective tissues surrounding the joints can impact joint range of motion (Michlovitz et al., 2004). Various approaches, including stretching exercises and techniques such as stretching exercises with heat, can be employed to facilitate a positive restoration of joint range of motion (Nakano et al., 2012).

It has been observed that more experienced gymnasts exhibit a narrower body sway range at a lower frequency when maintaining body posture in the standing position, in contrast to less experienced gymnasts. In simpler terms, experienced gymnasts manage to minimize body sway by applying greater force on the ground surface. Less experienced athletes may struggle to achieve this even after several years of training (Hart et al., 2018).

The outcomes of this study, however, indicate that the range of motion of the joints remains unaltered during handstand training when utilizing the teaching aid device developed by the researchers.

While the study findings indicated that the researcher-made teaching aid device didn't make a difference in elbow pain compared to the traditional method, it did lead to a significant reduction in pain experienced in the shoulder, back, and wrist areas. Given that the primary load-bearing responsibility for maintaining balance on the hands falls on the wrist and shoulder joints, the absence of thigh pain in the participants can be justified.

Furthermore, the nature of the researcher-made teaching aid device involves a gradual progression in which, as the learner advances, the height of the legs

and the deviation of the COP (center of pressure) shift toward the wrist and shoulder. This gradual shift means that the entire body weight is progressively supported by these joints. It appears that this is why the amount of pain in the wrist and shoulder was lower in the group learning the handstand with the researcher-made device compared to the group trained with the traditional method. In the traditional method, the center of pressure is not immediately transferred to the wrist and shoulder, which may explain the higher pain levels. However, it is crucial to enhance beginners' awareness of the correct function of the wrist, tailored to their skill level (Rohleder and Vogt, 2019). Practical applications: Utilizing an assistant device for handstand training in gymnastics results in reduced pain by redistributing central pressure from the wrists to the shoulders, hips, knees, and ankles over time. It also affirms that the device does not impact the range of motion or timing of the participants.

This research suggests that further investigations can be undertaken by other researchers to enhance and refine this device, exploring its effectiveness in enhancing neuro-mechanical control among gymnasts. This approach could potentially address the unresolved issues of the current device.

## CONCLUSIONS

In summary, when considering the same training conditions as the traditional method, including training duration, maintaining the quality of handstand performance, and not altering the range of motion of the joints, the researcher-made teaching aid device demonstrates the ability to reduce pain in the wrist, shoulder, and

back areas. Given that research has shown the positive impact of teaching style on learning (Khouri et al., 2020), it can be concluded that incorporating this instrument into the teaching of handstand movements is a more suitable approach than the traditional method. Therefore, its utilization is recommended in the teaching and training process.

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**Corresponding author:**

Mohamed Hosein Nasermeli  
Islamic Azad University, Karaj branch.  
Faculty of Physical Education & Sport  
Sciences, Iran, Alborz  
Phone and fax number: +989122611198  
Email: [mh.naser.m@gmail.com](mailto:mh.naser.m@gmail.com)

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