UDC796.412.2:378.016(497.751)
Research Article

KINEMATIC ANALYSIS OF HANDSTAND IN GYMNASTICS - Educational Gymnastics –

Fadil Mamuti[1] Fadil Rexhepi[2]

[1,2] *University of Tetova, Faculty of Physical Education*

Abstract

The purpose of this study is the evaluation of gymnastics handstand, as well as the kinematic analysis of the above mentioned technique as an integral part of the university curriculum.
Method of work. In this research were examined 18 students of the Faculty of Physical Education of University of Tetova who are in their second year of study and have already completed the sports gymnastics subject which is obligatory and lasts one semester. Each student was graded with sufficient, good, or excellent, by three gymnastics teachers. With the purpose of comparing the handstand techniques, a model of performance was examined by the student who performed the exercise best. For kinematic analysis the following parameters have been taken: angles and distances of the extreme points of the limbs of the body and center of gravity of the body. The Kinematic parameters were extracted with the System for kinematic analysis – APAS (Ariel Performance Analysis System), and their processing was done using the descriptive statistics and one-way ANOVA analysis.
Results of the kinematic analysis of angles show that the differences between the groups are not significant. Also results show that distances of the extreme points of the limbs of the body and center of gravity of the body do not show significant differences between the groups, for the three position indicators, respectively the distances mentioned above.
Conclusion: From the results obtained, there are no significant statistical differences between the ideal model chosen as the most successful performance and the three assessed student groups. Therefore, we can conclude that during the assessment of the students special care should be given to some characteristics that make the handstand to be performed technically correctly.

Keywords: gymnastics, handstand, assessment, descriptive statistics, kinematic analysis, ANOVA

Introduction

A handstand is a static acrobatic exercise, where the body is maintained in the equilibrium position with the hands pressed into the floor. As a key exercise of the contemporary gymnastics, it has evolved from the military training in ancient Greece (Tipton, 2011; Wikipedia, 2011). It is performed as a separate element in connection with other acrobatic elements and as a transitional position within another element's technique. The technical execution of handstand technique is governed by the evaluation rules (FIG, 2017). In artistic gymnastics, handstand is an acrobatic element that is an integral part of every gymnastic exercise and is present on all apparatus. For the correct performance of the handstand the following is important: strength of the entire body, coordination, orientation and flexibility of joints, especially shoulders (Uzunov, 2008; Yedon & Trewartha, 2003; Živčić Marković et al., 2015; Živčić Marković & Krističević, 2016).
Handstand is considered one of the key and basic technical exercises in sports gymnastics. It is so because it is performed on all the apparatus of the gymnastics all-around. The technical component of performing a handstand is described through the key points of the movement of certain body parts and body posture (Estape et al., 1999; Novak et al., 2008; Živčić, 2007): arms stretched at the shoulder-width; legs stretched and together; the emphasis of the pointed feet defining a straight line of the entire body; the position of the head in the extension of the spine (as in upright position) with the eyes looking at the fingers; the upper part of the back rounded with the maximum shoulder extension; the pelvis flat with the hips tucked in. Since the technical component of performing a handstand is described by the key points in the movement of certain body parts and body posture, i.e. four typical phases of

performance, it is possible to single out the most commonly used ones: 1. Initial position: With the arms extended overhead, 2. Lunge step and placing the hands onto the floor, 3. Back kick and take-off, and 4. Finishing position: Endurance in front lying support tucked in (Živčić Marković K., et al., 2015).
In a handstand position the body is in an upside down position and the equivalents of ankles and hips in an upright position are wrists and shoulders. Handstand is a basic movement structure in the system of activities in artistic gymnastics. It is a static unstable balance position. From mechanical point of view, its specificity is determined by the height of centre of gravity, size of support area and the overall difficulty of the balance position in which we maintain stability. The new trends in the technique of performance deal with three segmental strategies of balance correcting in a handstand position. An effort is to achieve a perfect body strengthening by isomeric contraction of abdominal, gluteal and back muscles, resulting in connection of segments legs – trunk and correction is done at a level wrist – shoulder (Hedbávný, P., et al., 2017).

The purpose of the research and previous studies

The purpose of this research is to compare some parameters that determine the handstand compared to the ideal model (conducted by the student that is rated as the most successful or ideal performer) for the II year students of the university level.
Current research shows that there is not a large number of researches conducted of kinematic analysis on gymnastics handstand on university students, but we will present similar researches that deal with the problem of this research.
Albrecht, L., et al. (1991) have researched the anthropometric characteristics of outstanding male and female gymnasts. Anthropometric data of outstanding gymnasts were gathered on the occasion of the 24th World Championship Artistic Gymnastics, held at Rotterdam, The Netherlands, in October 1987. In total 165 males and 201 females were investigated, constituting 84% of the total number of participants. The data of these gymnasts were descriptively compared with both reference data and data reported in previous studies on gymnasts competing at international events. Also, based on the data obtained, 'gymnastic-specific' anthropometric reference values (i.e. profile charts), were established for both male and female gymnasts. Finally, the maturational characteristics (skeletal age and menarche) of the 'Rotterdam' female gymnasts were described.
According to Kim Yon-Ji., et al (2006) the purpose of the study is to search for the possibility of the application of kinematics analysis to physical education at schools and expand its scope of application. This study chose 9 college students majoring in physical education and classified them into type A group who can make the straight, vertical handstand, type B group whose waist is bent, type C group who cannot handstand completely. The center of mass, distance between hand and leg, and the angle and angular velocity of each joint were obtained. This study confirmed that the time for phase of the CM, horizontal and vertical positions, velocity, the distance between hands and foot, and the difference of the angle and angular velocity of hip joint and shoulder joint can be set as the variables of analysis. It was also definite cause that the handstand motions of college students majoring in physical education had many difference in performance.
Belčič B., Samaržija Pavletič (2015) conducted research on 48 of Slovenia's most successful gymnasts (24 men and 24 women) to maintain the handstand balance on the tensiometric platform. Three parameters were evaluated, while statistical analyzes were applied to their values. The results have shown that there are no statistical differences between male and female gymnasts. But statistical differences between individual categories of disciplines have been observed, taking into account the overall speed up to the vertical (mm/s).
In the research, Kochanowicz et al. have researched the level of maintaining equilibrium between gymnasts and showed the link between sports results taking into account the importance and quality of exercise. The survey included children aged 11 to 12 who systematically took part in gymnastics (n=20), and experienced gymnasts aged 18 to 26 years with international achievements (n=12). Both groups are involved in national and international level competitions. Test results have shown that there is a statistical difference between the levels of maintaining the balance on the handstand.
Živčić K. M. et al. have conducted the research titled: "Properties of some kinematic parameters in handstand technique in artistic gymnastics". The aim of this study has been to determine the difference between key kinematic parameters of handstand phases. Results showed statistically significant differences ($p=0.00$) in the hip angle of the kick leg, the hip angle of the take-off leg, head angle and the duration of all phases of handstand. The Bonferroni post-hoc test showed the differences between the phases of handstand. Information were obtained about the significance of the hip angles, shoulders, and head in different stages of handstand execution. By precisely defining all kinematic parameters of handstand performance, it would be possible to early detect causes of mistakes and find the best way to eliminate them. This will help coaches to find the most important exercise and pay attention to key points of handstand.

There is a large number of theoretical research of the handstand related with: description of the technique, defining the most commonly encountered errors during the execution as well as the description and selection of methodological procedures during the teaching and learning educational process (Bolkovič, Kristan, 2002; Čuk et al., 2009; Kerwin & Trewartha, 2001; Novak et al., 2008; Yedon & Trewartha, 2003; Živčić Marković et al., 2012).

Methods of work

Sample of entities

The sample of entities consists of 18 second year students of the Faculty of Physical Education in Tetovo, who have followed one semester *gymnastics* subject according to ECTS. Based on the evaluation of the handstand, the students were divided into three groups: Gr. I n=6 sufficient, Gr. II n=6 good and Gr. III=6 excellent. All male students of the second year are included in the research.

Based on the criteria necessary for the correct performing of the exercise, the assessment has been realized in three levels: sufficient, good and excellent. Since it is mainly connected with gymnastics of pedagogical character at the university level, the handstand technique is used as the ideal technique, executed by the best practitioner based on the criteria necessary for assessment. After clarifying the purpose of the research, the students volunteered to participate in the abovementioned gymnastic exercise.

Samples of variables

As a criterion, three levels of assessment were evaluated: sufficient, good and excellent, evaluated by three gymnastics professors, while the ideal model for the execution was the most accurate technique implemented by the best performer.

From the anthropometric characteristics, these parameters are evaluated:

Body Height and Body Mass.

For kinematic analysis the following parameters have been taken:

a. The Angles: Ankle angle, Knee angle, Arm angle and Elbow angle.

b. Distances of the extreme points of the limbs of the body and center of gravity of the body:

The distance of the toe from the floor, The distance of the toe from the center of gravity of the body, and The distance of the center of gravity of the body from the floor.

The aforementioned variables in this research define the success of the technically correct execution of the handstand.

Description of the measurement process and measuring equipments

The measurements were carried out in the gymnastics hall of the Faculty of Physical Education of the University of Tetova in optimal conditions. The sports gymnastics program takes place in the second year of study. After the proper warm up and the stretching of the body, the students carry out the exercise by 3 times, while for the analysis the best performance is obtained from the three attempts.

It is worth pointing out that all the students prior to the assessment have followed the methodical exercises during the learning. Before realizing the handstand, all the students were explained the demonstration protocol of the technique and its evaluation.

Evaluation as usual starts from the moment the practitioner raises the leg from the ground and ends when the practitioner begins to fall from the vertical position, which usually needs to be maintained for up to two seconds.

For achieving the study objectives and assessing the success of the performance of the exercise, the APAS - Ariel Performance Analysis System is used. The performance of exercise by all subjects (students) is filmed with three Sanyo digital cameras (60Hz/s) located at an angle of about 120 degrees from each other. The distance of the cameras from the venue of the performing handstand is 8 meters.

The filmed material is processed according to the process of the APAS System modules. For each subject, the last 15 frames were cut, respectively; the last frame of the static position of the exercise was analyzed. Digitalization of the filming is done according to the model of the gymnastic body's leverage formed by 18 points of his body (figure 1). After the digitization has become the transformation of the model of figures from 2D to 3D. Then filtering of the signal (movement curve) for each point analyzed is done. Finally, the data from the curves obtained for the angles and the position of the gymnast’s body are read.

Figure1. Handstand position - excellent performance (sagittal and frontal plane)

Method of processing the data

Except the assessment made by the gymnastics teachers, after processing the values for the variables concerned, their processing was done with the help of the SPSS statistical program. For the three groups of evaluated students, the statistical parameters were described, while the variance analysis method (ANOVA) was applied for the confirmation of the significance difference of the variance between the three groups.

Results and Discussion

In Table 1, are reflected the values of the main indicators describing the position of the gymnast's body during the realization of the handstand technique. For both morphologic indicators body mass and body height, it can be seen that students who were rated with 'excellent' marks during the exercise have smaller values of these two main dimensions of the body. This data is an understandable characteristic of this discipline, where it is well known that gymnasts with smaller body sizes have better success in carrying out the gymnastics exercises and technical elements. More information about anthropometric characteristics of outstanding male and female gymnasts can be seen in the work (Claessens, A et all., 1991).

Table 1. Descriptive Statistics

VARIABLES	GRUPI	N	Minimum	Maximum	Mean	Std. Deviation
ABH (cm)	SUFFICIENT	6	165,00	195,00	179,5000	10,07472
	GOOD	6	175,00	190,00	179,3333	5,81951
	EXCELLENT	6	162,00	179,00	173,0000	5,76194
ABM (kg)	SUFFICIENT	6	60,00	85,00	78,6667	9,93311
	GOOD	6	70,00	90,00	78,3333	6,77249
	EXCELLENT	6	60,00	82,00	69,8333	7,98540
KANKA (°)	SUFFICIENT	6	98,00	139,00	125,1667	14,16216
	GOOD	6	99,00	140,00	126,1667	14,91867
	EXCELLENT	6	109,00	143,00	125,6667	13,41144
KKNEA (°)	SUFFICIENT	6	142,00	178,00	168,3333	13,98094
	GOOD	6	164,00	179,00	173,3333	5,16398
	EXCELLENT	6	172,00	178,00	175,8333	2,40139
KARMA (°)	SUFFICIENT	6	126,00	158,00	144,6667	11,69045
	GOOD	6	112,00	152,00	136,0000	17,07630
	EXCELLENT	6	140,00	161,00	154,0000	7,87401
KELBA (°)	SUFFICIENT	6	143,00	174,00	159,1667	11,85608
	GOOD	6	134,00	172,00	159,0000	15,42725

	EXCELLENT	6	166,00	174,00	171,1667	2,99444
KDTF (cm)	SUFFICIENT	6	185,00	234,00	204,1667	18,17049
	GOOD	6	177,00	231,00	204,5000	18,16315
	EXCELLENT	6	191,00	211,00	203,5000	8,40833
KDTCG (cm)	SUFFICIENT	6	84,00	107,00	95,1667	9,36839
	GOOD	6	82,00	108,00	94,8333	9,38971
	EXCELLENT	6	90,00	97,00	94,5000	2,88097
KDCGF (cm)	SUFFICIENT	6	109,00	130,00	116,0000	7,58947
	GOOD	6	104,00	129,00	116,0000	9,20869
	EXCELLENT	6	107,00	118,00	113,1667	4,79236

Indicators describing the position of the gymnast's body are the angles: on the ankle (talocrural) articulation, the knee articulation, the arm articulation and the angle of the elbow articulation. From Table 1, it is seen that the value of ankle articulation angle for students with 'sufficient' is 125.16°, for students rated 'good' the angle ankle articulation is 126.16°, while for the students estimated with 'excellent' the value of the ankle articulation angle is 125.66°. Table 2 shows that differences between the three groups are not significant. This means that the maximum extent of the toe is almost the same in all three groups, but compared to the results of the ideal realization is not satisfactory either to the group rated with 'excellent'. The best result in the excellent group is 143.00°, which means that there is better toe extension on the talocrural articulation.

The good position of the gymnast's body also means the maximum extension of the lower limbs in the knee articulation. This value estimated for students group with 'sufficient' is 168.33° for 'good' valued group 173.33 °, while for the 'excellent' group the knee articulation angle value is 175.83°. Even though the greatest knee articulation value is the 'excellent' group, being followed by the 'good' group, table 2 shows that the differences between the groups are not significant.

The angle in the articulation of arm has shown the largest value with the appraised 'excellent' group (154°), then followed by the 'sufficiently' rated group, while the lesser value is in the 'good' rated group. Even for this indicator there are no significant differences between the groups. The angle at the elbow articulation as well as the other angles values the highest value is at the 'excellent' group (171.16°), while in the other two groups this indicator has almost equal values. The aim of the gymnasts is to have this articulation maximally stretched, respectively the value of the angle attempt to reach 180°. Other kinematics parameters data for handstand can be found in a similar research by authors (Živčić K. M. et all 2018).

The body position of the gymnast, except to the angles in the main articulations of the body limbs during the performance of the technique handstand, also depends on the optimal distance of the extreme points of the body: the toe tip of the toe extending maximally from the body center of gravity, the distance of toe tip of the toe extended maximally from the floor, the center of gravity of body distance from the palms. The best position is if your body and limbs are maximally stretched so that these distances need to be bigger. But such a thing except that it depends on the maximum extent, it also depends on the constitution of the gymnast's body, respectively the size of his body, and especially his length. From Table 1, it can be seen that 'excellent' valued gymnasts have lower body height compared to the other two groups by about 6,5 cm, as well as the shortest limbs. But the values of the three distances mentioned above in the 'excellent' group are almost the same as the values of the other two groups, which means that they have better stretch of body as a whole, so they have such a result. Table 2 shows that there are no significant differences between the groups, for the three position indicators, respectively the distances mentioned above. Research on the distance between hands and feet was also made by the authors (Kim et all., 2006).

Table 2. Confirmation of the significance of differences between groups (ANOVA)

One way

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
ABH	Between Groups	164,778	2	82,389	1,466	,262
	Within Groups	842,833	15	56,189		
	Total	1007,611	17			
AMB	Between Groups	300,778	2	150,389	2,166	,149
	Within Groups	1041,500	15	69,433		
	Total	1342,278	17			
KANKA	Between Groups	3,000	2	1,500	,007	,993
	Within Groups	3015,000	15	201,000		
	Total	3018,000	17			
KKNEA	Between Groups	175,000	2	87,500	1,152	,342
	Within Groups	1139,500	15	75,967		
	Total	1314,500	17			
KARMA	Between Groups	972,444	2	486,222	2,975	,082
	Within Groups	2451,333	15	163,422		
	Total	3423,778	17			
KELBA	Between Groups	584,111	2	292,056	2,261	,139
	Within Groups	1937,667	15	129,178		
	Total	2521,778	17			
KDTF	Between Groups	3,111	2	1,556	,006	,994
	Within Groups	3653,833	15	243,589		
	Total	3656,944	17			
KDTCG	Between Groups	1,333	2	,667	,011	,989
	Within Groups	921,167	15	61,411		
	Total	922,500	17			
KDCGF	Between Groups	32,111	2	16,056	,291	,751
	Within Groups	826,833	15	55,122		
	Total	858,944	17			

Conclusion

During the learning of the gymnastic technique handstand special importance should be paid to methodical and didactic principles as well as to the most common mistakes in the process of learning. The school technique requires the practitioners to have the final handstand hold out for at least 2 seconds. By precisely defining all kinematic parameters of handstand performance, it would be possible to early detect causes of mistakes and find the best way to eliminate them. This will help coaches and teachers to find the most important exercises and pay attention to key points of handstand. Also, it will be necessary to analyze the kinematic parameters in exercises that serve for learning the handstand technique (Živčić Marković K., et al., 2018).

The descriptive statistics reflect the values of the main indicators describing the position of the gymnast's body during the realization of the handstand technique. For both morphologic indicators body mass and body height, it can be seen that students rated with 'excellent' marks during exercise have smaller values of these two main dimensions of the body. This data is an understandable characteristic of this discipline, where it is well known that gymnasts with smaller body sizes have better success in carrying out the gymnastics exercises and technical elements.

Results of the kinematic analysis of angles (body position) show that the differences between the groups are not significant. Also results show that distances of the extreme points of the limbs of the body and center of gravity of the body have no significant differences between the groups, for the three position indicators, respectively the distances mentioned above.

From the results obtained, there are no significant statistical differences between the ideal model chosen as the most successful performer and the three assessed student groups. So, we can conclude that during the assessment of the students, special importance should be paid to some characteristics that make the handstand to be performed technically correctly.

References

[1]. Tipton, J. (2011). *Types of Handstands* /on-line/. Retrieved on 05th November 2018 from http://www. ehow.com/facts_5279611_types-handstands. html.

[2]. Uzunov, V. (2008). The handstand: A four stage of training model. Gym Coach Journal, 2, 52-59.

[3]. Estape, E., Lopez M., & Grande, I. (1999). Las habilidades gymnasticas y acrobaticas en el abito edzcativo. Barcelona: INDE Publicaciones.

[4]. Živčić Marković, K.., Krističević, T., Aleksić-Veljković, A. (2015). A suggested model of handstand teaching method. Physical Culture 69 (2), 138-149.

[5]. Živčić Marković, K., Milčić, L., Krističević, T., Aleksić-Veljković, A., Lagančić, T. (2018). Kinematical differences of handstand technique. In D. Bjelica, S. Popović, S. Apkinar (Eds.), Book of abstracts of 15th International Scientific Conference on Transformation Process in Sport "Sport Performance" (pp. 16-17). Nikšić: Montenegrin Sports Academy.

[6]. Živčić Marković, K., Milčić, L., Krističević, T., Breslauer, N. Lanc, D. (2018). Properties of some kinematic parameters in handstand technique in artistic gymnastics.

[7]. https://bib.irb.hr/datoteka/946091.Properties_Of_Some_Kinematic_Parameters_In_Handstand_Technique_ In_Artistic_Gymnastics.pdf

[8]. Hedbávný P., Sklenaříková J., Hupka D., Kalichová M. (2017). Balancing Handstand on the Floor… Vol. 5 Issue 3: 69 – 80.

[9]. Novak, D., Kovač, M., & Čuk, I. (2008). Gimnastična abeceda. Ljubljana: Fakulteta za šport Univerze v Ljubljani. [Gymnastics ABC. Ljubljana: Faculty of Sport University of Ljubljana].

[10]. FIG (FIG). Code of Point. Moutier. Federation International de Gymnastique.

[11]. YJ Kim, JM So, HC Yeo (2006). A Kinematics Analysis of Handstand of University Students Majoring in Physical Education. Korean Journal of Sport Biomechanics. koreascience.or.kr.

[12]. Albrecht, L., Claessens, Veer, F M., Stijnen, V., Beunen, G., Lefevre, J., Maes, H., Steens, G. (1991). Anthropometric characteristics of outstanding and female gymnasts. Journal of Sports Sciences 9(1):53-74.