STABILITY TRAINING AND EFFECTIVENESS OF PLAYING BASKETBALL

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Abstract The aim of this study is to review the available literature for factors affecting a basketball throw and the stabilization of the trunk. Searching for the most important elements which ought to be improved during training to increase the effectiveness of a throw and those which condition the correct stabilization of the trunk.

The obtained results, after analyzing the literature, show that it is not possible to determine a single factor affecting a throw and the stabilization of the trunk. There are many factors that influence each other and, therefore, must be trained as one. There are biomechanical relationships between the effectiveness of making a throw, the positioning of the limbs, the trunk and the trajectory of the ball. It is important to mention the role of a factor outside biomechanics, such as the player's psyche. Muscles have the greatest impact on stabilization. Muscle function would not be possible without proper control by the nervous system

The conclusion section shows a large number of interacting factors responsible for the quality and effectiveness of the throw as well as for the stabilization of the trunk. This allows better planning and conducting of basketball training aimed at improving technique and throw effectiveness.

Key words basketball, free throw, core stability, trunk control

Introduction

Basketball is a sport in which players must make many decisions. The estimated number of people playing basketball around the world is 450 million (Bonato, Benis, La Torre, 2018). This shows how greatly popular this sport is. The most important aspect of basketball is a) when, b) where, c) from and d) how to take a shot in order to score points. If a shot is taken with the minimal usage of energy it means that the player is the most stable and the shot has a greater probability of finding its way into the basket (Huston, Grau, 2003). The share of shots for two points is estimated at 41%, whereas the number of shots taken from a distance is variable, depending on the prowess of the team (Tang, Shung, 2005). The authors state that in better teams the percentage is higher than 45%, whereas in weaker teams it is around 35%. Free throws are one of the most important elements in basketball, as 20% of all points scored during a game is scored from the free-throw line. Many matches are won or lost over this element of the game (Kaya, Callaghan, Donmez, 2012; Oancea, Ionescu, 2015). Ordinarily, two throws are made (the exception being when points are scored when fouled, which results in the points being awarded and one free

throw is carried out) and are always performed from the same place without the participation of the defence, jumps and pivots (Gomez, Avugos, Onoro, 2018; Hung, Johnson, Coppa, 2004).

W.T. Tang and M. Shung (2005) state that the most important factor in the effectiveness of an in-game throw is the shot angle of the ball. They also stated that the average speed of a 2-point throw is 5.27 m/s and 8.39 m/s for 3-point throws. Other authors emphasize the importance of linking together basic motor skills (jumping, running), psyche and training (Savas, Yuksel, Uzun, 2018). There are many elements influencing the effectiveness of carrying out free throws. The available literature accurately describes the technique of a throw, from the positioning of the lower limbs, trunk and upper limbs (Kaya et al., 2012; Ball, 1989; Stankovic, Simonovic, Herodek, 2006; Tang, Shung 2005; Oancea, Ionescu, 2015; Cetin, Murati 2014; Podmenik et al. 2017), through the mechanics and timing of the releasing of the ball (Verhoeven, Newell, 2016; Cetin, Murati, 2014), putting on the proper rotation (Huston, Grau, 2003), ending with the psychological aspect (Gomez et al., 2018; Verhoeven, Newell, 2016; Ocak, Savas, Isik, 2014; Su, Yang 2018). The correct biomechanics of the free throw has been widely written on. It defines the bending of the knees, keeping the elbow ideally below the ball, using all five fingers to support the ball, throwing using the elbow joint as a pendulum, putting rotation on the ball by finishing the throw with a flex of the radiocarpal joint and also tilting the trunk forward (Kaya et al., 2012; Hung et al., 2004; Podmenik et al. 2017). An important element that has been written about by authors is the recreation of the finishing of the throw and a stable posture (Gomez et al., 2018; Verhoeven, Newell, 2016; Oanecea, Ionescu, 2015; Cetin, Murati, 2014; Barbieri, Rodrigues, Polastri, 2017; Dong, Yang, Pu, 2014). Of course, there exists a relationship between the accuracy of free throws and the time and type of training (Huston, Grau, 2003; Savas et al., 2018; Ocak et al., 2014). A. Schmidt (2012) presents the free throw as a game of joints in a closed kinematic chain, in which good stability and mobility on all levels involved in the movement are needed. He states that in more advanced players, who are better at free throws, it can be observed that during the throw greater global stability and better peripheral mobility is shown. Furthermore, the position on the court determines better (positions 1, 2, 3) or worse (positions 4, 5) efficacy of performing a free throw (Sindik, 2015). These parameters allow for the assessment of free throws not only in terms of accuracy but also in terms of whether it has been performed correctly. Thanks to this, it is possible to determine which aspects an individual player needs to improve during training for their free throws to be more effective.

The first aim of this study is the exploration of available literature that indicates elements influencing a free throw in basketball. The second aim is the demonstration of factors conditioning good stabilization of the trunk as significantly influential on the quality and effectiveness of free throws.

Material and methods

The review of the literature concerned factors which influence the effectiveness of free throws in basketball and the elements that condition the stabilization of the trunk during the throws. The analysis was conducted in March of 2019 from the databases of PubMed, ScienceDirect, Ebsco and Springer. The criteria, with regard to what would be included or excluded, were defined to narrow down the number of articles reviewed. This criterion was introduced on the basis of the analysis of titles and introductions of said works regarding the technique of a free throw in basketball and factors affecting the stability of the trunk. Due to the lack of significant changes in the technique of free throws over the years, the analyzed articles were published in the year 2000. Articles regarding stabilization of the trunk were published within the last 5 years.

The articles were reviewed if they met the following inclusion criteria:

1. The subject of the work concerned the technique of carrying a free throw in basketball or factors influencing the stabilization of the trunk.
2. The study regarded sport/basketball/training of the core.
3. The study did not describe the effects of specialist training.
4. The study included results from the most recent studies regarding the technique of a free throw from the year 2000, and regarding the stabilization of the trunk – from the last 5 years.

The review rejected papers if they contained the following exclusion criteria:

1. The study did not regard sport/training of the core.
2. The study took note of the external factors influencing the free throw.
3. The study took note of the effects of specialist training.
4. The study included data stretching back further than the year 2000 regarding the technique of the free throw or further than 5 years regarding the stabilization of the trunk.

The keywords and the resulting key phrases used in this article are basketball, free throw, torso stability (central stability) and trunk stability. After entering all key word phrases from more than 25,000 papers regarding throws in basketball, 331 papers remained. However, from over 500,000 works regarding the stabilization of the trunk, about 400 works remained after entering the key phrases. After the addition of the correct criteria of inclusion and exclusion and abstract analysis, 28 works remained regarding the technique of the free throw, and regarding the factors affecting the stability of the trunk – 14 works. Works were excluded from the analysis if they did not concern issues related to sport or specialized sports/stabilization training. Works describing the impact of external elements influencing a throw such as the texture of the board, the material of the ball, color and material of the court floor were not taken into account. Furthermore, works were excluded if they included pilot studies or if they did not fall within the set time frame. The two most important aspects of this analysis were determining (a) the factors influencing a throw in basketball and the elements on which (b) conditioned the stabilization of the trunk in an athlete.

Results

Technique and biomechanics of carrying out a throw

D. Kaya (2012) and G. Hung (2004) very accurately state the technique for carrying out a free throw. In the starting position, the knee joints should be bent at 90° and the trunk should be inclined vertically in the direction of the bend at 50°. The authors also determine the flexion of the shoulder joint when releasing the ball to be 140–150°. They highlight the large role of cooperation between the torso, knees, ankle joints and upper limbs that they play during a throw – knees, ankle joints and torso straighten up, and at the same time the shoulder joint bends (Kaya et al., 2012; Hung et al., 2004). B.M. Oancea and R. Stankovic add the alignment of the shoulder, elbow and radial joint within the projection line and parallel to each other (Oancea, Ionescu, 2015; Stankovic et al., 2006). This is also confirmed by V. Okazaki, who adds the vertical positioning of the forearm during the throw and the positioning of the elbow joint perfectly under the ball (Okazaki, Rodacki, Satern, 2015). The authors highlight the beginning of the throw underneath the chin and ending it over the head, also finishing with flexion of the wrist and further phalanges which put spin on the ball – spin meaning reverse rotation which allows for the ball to bounce off the board in the direction of the basket. Ch. Tran determines that the ideal frequency for rotation is 3Hz. The same author states that the aforementioned average height from which the ball is released over the head of the thrower

is about 15 cm (Tran, Silverberg, 2008). M.-A. Gomez describes the large role of the "non-throwing" hand which until the last moment helps to keep the ball on the throwing hand, stabilizing it during a throw (Gomez et al., 2018). V. Okazaki highlights the use of the weight of the ball to give it momentum by utilizing a hyperextension in the radial-carpal joint (Okazaki et al., 2015). C. Button and D. Mullineaux state, however, that the biggest factor in giving the ball speed is the extension of the elbow joint (Button, Macleod, Sanders, Coleman, 2003; Mullineaux, Uhl, 2010). Thanks to these movements, the proper flight angle of the ball is accomplished, which G. Hung sets at 56–59°, in order to obtain the ideal angle of the ball's entry to the basket – 45° (Hung et al., 2004). However, analyzing other authors, such as F.J. Rojas, H. Nunome, L. Malone, V. Okazaki and A.L.F. Rodacki, the flight angle of the ball is set at between 44 and 63° (Rojas et al., 2000; Nunome et al., 2002; Malone et al., 2002; Okazaki et al., 2015; Rodacki et al., 2002). Finally, M. Verhoeven and V. Okazaki highlight the role of stabilizing the body during a throw. The former author demonstrates the differences when the ball is released from the hands in terms of shifting the centre of gravity between players shooting free throws with greater and lesser effects. The second author shows the impact that the lack of a stable torso has on the swing of the upper limbs outside the correct (in line with the basket) path (Verhoeven, Newell, 2016; Okazaki et al., 2015). In addition to this, Q. Huang provides information regarding the impact of the throw itself on the loss of stability based on the shift in the centre of gravity during a throw. This means that during elevating the ball for a throw, the player loses stability. The player must possess a very high level of stability for this loss to not affect their accuracy (Huang, Hodges, Thorstensson, 2001). Confirmation of this may be the work of L. Malone, in which he assesses the effectiveness of players playing basketball on wheelchairs, and highlights that the weaker shooters are those which, due to their disability, experience problems with stabilizing their trunk (Malone et al., 2002).

Table 1. Factors influencing the effectiveness of a throw according to the literature

Author	Factor	Value	Phase of the throw
1	2	3	4
D. Kaya et al., 2012 G. Hung et al., 2004	Angle of bent knees Vertical tilt angle of the trunk Flexion of the shoulder joint	90° 50° 140–150°	Finishing position Releasing the ball
B.M. Oancea, B.D. Ionescu, 2015 R. Stankovic et al., 2006	Linear alignments of the elbow, shoulder and radiocarpal joint	–	Starting position Elevating the ball
V. Okazaki et al., 2015	Vertical position of the forearm	–	Starting position Elevating the ball
Ch. Tran, L. Silverberg, 2008	Putting on spin Finishing the throw above the head	3Hz 15 cm	Releasing the ball Releasing the ball
V. Okazaki et al., 2015 C. Button et al., 2003 D. Mullineaux, T. Uhl, 2010	Giving momentum to the ball: Hyperextension of the wrist joint Extension of the elbow joint	–	Releasing the ball
G. Hung et al., 2004 F.J. Rojas et al., 2000 H. Nunome et al., 2002 L. Malone et al., 2002 V. Okazaki et al., 2015 A.L.F. Rodacki et al., 2002 W.T. Tang, M. Shung, 2005 N. Podmenik et al. 2017	Release angle of the ball	44–63°	Releasing the ball

1	2	3	4
M. Verhoeven, K.M. Newell, 2016; V. Okazaki et al., 2015; Q. Huang et al., 2001; F. Barbieri et al., 2017; A. Schmidt, 2012; F. Dong et al., 2013; E. Cetin, S. Murati, 2014	Stabilisation of the trunk	–	Starting position Elevating the ball Releasing the ball
Y. Ocak et al., 2014; S. Savas et al., 2018; R. Huston, C. Grau, 2003	Training time and prowess	–	–
M.-A. Gomez et al., 2018; B.M. Oancea, B.D. Ionescu, 2015; Y. Ocak et al., 2014; J. Su, B. Yang, 2018	Psyche	–	–

Repeatability of the starting position and stable posture

As M.-A. Gomez describes, free throws are always carried out from the same place without the participation of the defence. This allows for the opportunity to train the repeatability of the throw and the proper stable posture accordingly, in order to ensure throws are as effective as possible (Gomez et al., 2018). The analysis of the available information reveals that one of the most important factors influencing the repeatability of free throws is the stability of the player. A. Ahmed and Y. Kim clearly state that responsible for the motor control of the trunk are the corresponding muscle groups in between chest and pelvis, commonly referred to as the “belly”. The authors divide these muscle groups into motor and stabilization muscles. Both of these groups generate the appropriate tension responsible for maintaining a stable trunk. The co-contraction of these muscle groups and the proper timing of their tensions is decisive in determining the stability of the torso in a standing position but also in any other position required in a related sporting discipline (Ahmed, Waquas, Ijaz, 2017; Kim, Kim, Yoon, 2015). A. Joyce, and S.G. Grenier before him, supplement this information with how the stomach tenses. Distinguishing two ways, they state that the most appropriate/correct method of tension is called “bracing”, which not only allows for the tension of the transverse abdominal muscle but all muscles contained between chest and pelvis (Joyce, Kotler, 2017; Grenier, McGill, 2007). J. Muller, however, reminds us that the strength of trunk muscles conditions the ability to absorb external loads on the body (Muller, Muller, Stoll, 2014; Prieske et al. 2016). R. Szafraniec, K. Anderson and E. Whyte suggest that correctly tensed and appropriately activated trunk muscles allow for greater motor control within limbs, which allows not only for the prevention of injury but also more effective movement during competition and training (Szafraniec, Barańska, Kuczyński, 2018; Anderson, Deluigi, Belli, 2016; Whyte, Richter, O’Connor, 2018). D. Barbado also describes the strength and quality of trunk muscle tension as a decisive factor for a stable trunk during sports (judo, kayaking). Comparing two groups of athletes, amateurs and professionals, he decisively states that a greater and better trunk tension is seen within the professional group. This manifests itself as a better reaction time of the torso muscles to loads, which in turn allows players for more effective and quicker usage of motor muscles during training and competition. The same author highlights that strength training of the trunk stabilization muscles should be specifically tailored to every sports discipline (Barbado, Barbado, Elvira, 2016). In turn, P. Paula Lima claims – by using the example of people training capoeira – that apart from the strength of torso muscles, a large part in stability is played by the balance between antagonistic groups of muscles. This

sport requires many complex movements in which balance plays a major role, allowing the body to adapt to perform them (Paula Lima, Camelo, Ferreira, 2017). Similarly, G. Glofcheskie describes an athlete's ability to adapt to changing conditions during competition and to immediate situations by showing the differences in trunk stabilization in response to immediate situations in athletes and people who do not train. A decisive majority of athletes showed a good, quick reaction of torso stabilizers which allow to prevent injury (Glofcheskie, Brown, 2017). I. Jeon, and much earlier J. Peltonen, highlights a very clear role of the lumbar muscle (PSOAS) as one of the torso stabilisers (Jeon, Kwon, Weon, Choug, Hwang, 2015; Peltonen, Taimela, Erkintalo, 1998). At this point it ought to be noted that L. Cavaggioni states that one of the most important elements that allows for the correct stomach tension and hence a stable posture is the correct rhythm of breathing (Cavaggioni, Ongaro, Zannin, Iaia, Alberti, 2015. T. Vasconcelos also highlights breathing as a key element of muscle function, both those stabilizing the posture and those carrying out the movement (Vasconcelos, Hall, Viana, 2017). P. Hodges adds the role of the diaphragm, which is not only a respiratory muscle but also a stabilizing one, which allows for the maintenance of correct posture, i.e. during upper limb movement (throwing) (Hodges, Gandevia, 2000). These studies demonstrate how important breathing is with regards to the stabilization of the trunk and movement of the limbs. In 2008, D. Alpini added and M. Ditroilo confirmed in 2018 that apart from control gained through muscle strength stability, motor control is influenced by sight, sensory-motors and the proper functioning of the vestibular system (Alpini, Hahn, Riva, 2008; Ditroilo et al., 2018). Alpini highlights the changes in the centre of gravity in different audiovisual conditions, assessing the possibilities of an athlete adapting to them, by using the example of ice hockey and stating the adaptability strategies that allow for maintaining proper stability despite the occurrence of destabilising bumps.

Table 2. Literature regarding factors responsible for trunk stability

Author	Factor	Effect
Ahmed et al., 2017; Y. Kim et al., 2015	Co-contraction of motor and stabilisation groups in the trunk	Better motor control of the trunk
A. Joyce, D. Kotler, 2017	Correct tension of muscles between the chest and pelvis – stomach	Trunk stabilization
J. Muller et al., 2014; D. Barbado et al., 2016 O. Prieske et al., 2016	Strength of trunk muscles	Absorption of external forces
R. Szafraniec et al., 2018; K. Anderson et al., 2016; E. Whyte et al., 2018	Correct activation of trunk muscles	Better motor control of the limbs
P. Paula Lima et al., 2017; G. Glofcheskie, S. Brown, 2017	Balance between antagonistic groups of muscles within the trunk	Better reactions to immediate forces of changes of conditions
I. Jeon et al., 2015	PSOAS tension	Trunk Stabilizatio
L. Cavaggioni et al., 2015; T. Vasconcelos et al., 2017	Correct breathing and function of the diaphragm	Stable Trunk More effective function of stabilizing and movement muscles
M. Ditroilo et al., 2018	Sight, sensory-motor function, vestibular system	Effectiveness of stabilization muscles

Discussion

The first aim of this study was the determination of factors influencing a free throw in basketball. Based on the carried out review of the available literature, there is not one most significant factor impacting the quality of the

throw. These factors also influence each other, which means that training of at least a few of them at the same time allows to concretely improve the technique and effectiveness of the throw. The factors discussed in this review are not only biomechanical factors, such as the release angle of the ball, correct flexion angles of the shoulder joint, knee and elbow, correct positioning of the limbs tasked with the throw or most importantly the stabilization of the trunk. The psyche, training regime and control of breathing is also very important.

It must be highlighted that not all of the authors held biomechanical factors as the dominant with regards to improving the effectiveness of a free throw in basketball. Some of the authors selected the players' psyche as the decisive element (Gomez, Kreivyte, Sampalo, 2017; Oancea, Ionescu, 2015; Ocak et al., 2014; Su, Yang, 2018). The amount of literature addressing this element shows how important it is within the game. It is very difficult to clearly state whether biomechanical or psychological elements are more important with regards to the accuracy of throws during a game (where match emotions are present). M.-A. Gomez accurately describes that players are vulnerable to greater psychological forces in the last 5 minutes of the match, which can cause the accuracy of throws to decrease, even in well trained and stable players (Gomez et al., 2017).

The greatest analysis found in the literature concerns the throw angle of the ball, however it must be noted that authors do not link this parameter with others, which does not allow for conclusive findings regarding what has the greatest influence on establishing this angle, which evolves with time (Rojas et al., 2000; Nunome et al., 2002; Malone et al., 2002; Okazaki et al., 2015; Rodacki et al., 2002). This allows to put forward a hypothesis that other factors condition the value of the throw angle and its variability is caused by constant changes regarding the ideal or, most likely, multiple ideal ways of carrying out a free throw. This makes interpretation much more difficult for researchers and forces them to constantly monitor advancements in techniques.

A subsequent and often written about element is the stabilization of the trunk during a throw. However, the authors do not describe its interaction with other parameters. Many articles show stabilization of the trunk as a decisive factor, not only in terms of accuracy of a basketball throw, but also in other sporting disciplines. The amount of publications on this topic shows the weight of this parameter within sport and direct training efforts to focus on this element (Gomez et al., 2018; Verhoeven, Newell, 2016; Oancea, Ionescu, 2015; Cetin, Murati, 2014; Barbieri et al., 2017; Dong et al., 2013; Schmidt, 2012). The sole stabilization of the trunk is vastly influenced by many factors stated in this review of literature. This means that when planning stability training for basketball players, the possibility of training the greatest number of interchangeable factors ought to be taken into account. The literature lacks accurate research which analyzes elements impacting stability during a throw, which opens up the possibility of researching this parameter more closely.

Hence, the second aim was to state what the literature deems as factors conditioning good and proper stability of the trunk, which in turn impacts the effectiveness of the throw.

These factors are predominantly: proper breathing, motor control conditioned by the correct tension and strength generated by the appropriate muscles. Another important element appears to be the nervous system, which is responsible for the normal functioning of trunk stabilization.

The majority of authors within the analyzed literature states that correct activation of trunk muscles is the most influential factor in trunk stabilization (Szafraniec et al., 2018; Anderson et al., 2016; Whyte et al., 2018). This shows that today this parameter appears to be a priority when shaping a stable trunk. At the same time, it is important to highlight the fact that authors very widely direct attention to other elements influencing a stable trunk, such as breathing, which in 2013 was written on by Leon Chaitow (2013) and later in 2017 by B. Anderson and K. Biliven.

Second is the lumbar muscle and its activation about which we are able to read about in J. Peltonen and coworkers' paper (1998) (Jeon et al., 2015). All articles state a primary parameter responsible for the stabilization of the trunk, but it must be highlighted that none of the authors claims that it is one single factor. This means that the conclusions drawn from the literature agree with the fact that in order for good stabilization to be attained it is not possible to take into account only one factor. This is important when planning stability training in sport.

While providing such a large number of factors conditioning maintaining a stable trunk, the information from literature also provide a vast array of possibilities in terms of working with an athlete, in order for this important parameter to improve. There exist many forms of training the motor control which improves stability in athletes. N. Kofotolis proposes Pilates as a form of such training. He shows the impact of exercise of this kind on the positioning of joints, concentration, breathing and control of the trunk. He describes the possibilities of minimizing the pain, functional instability and asymmetricity during a 12-month training program. He also highlights the important role of peripheral mobility joints, not only the stability of the trunk as elements that increase the effectiveness of training (Kofotolis et al., 2016). However, M. Comerford states that the time period in which training should bring about effects is 3–4 months (Comeford, Mottram, 2017).

Analyzing and summarizing the above review of literature, it must be stated that seeking to introduce training that improves the quality and effectiveness of free throws must first and foremost focus on the stability of the trunk, which is conditional on a very large number of factors but allows for the sculpting of others that influence a throw, creating a foundation for improvement. This is why when planning stability training one should take into account the remaining elements influencing a free throw. Due to this, training this way increases the chance to change the quality of a free throw and the effectiveness of a player in an element of the game by improving the nerve and muscle control.

Conclusions

1. Many biomechanical and psychological factors exist, which impact free throws in basketball. Analyzing the performance of a throw and planning training that improves its quality and accuracy ought to take into account the number of these factors. It should be remembered that these factors are variable. This does not allow to clearly determinate the biomechanics of a perfect free throw. It is obvious that every researcher wants to find it, determine the most important factor and check interaction with other variables during research. With this interaction it will be possible to determine which factor will affect the largest number of variables, and will be considered crucial for the correct throw.

2. One of the most important factors in a free throw is good trunk stabilization, which is influenced by motor control resulting from tension, timing and strength of muscles which are located between chest and pelvis. It should be noted that today's stabilization training takes various forms. That is the main reason why it should be planned based on the movements which are made during the throw, in relation to possible research. Exercises proposed by researchers during possible tests, and when planning basketball training, should ideally be matched to the elements affecting the player during the throw. It could be concluded, based on this review, that the priority would be activation of the abdomen and maintaining it during the movement from squat to extension, as it happens during the throw.

3. The most important is the functioning of the nervous system, which ensures good nerve muscle control, and what comes with that is good stabilization and control of movement during a throw.

The conclusions of this review show how important it is to determine the factor that has the greatest impact on other factors, and generally on the free throw. According to this review, the stabilization of the torso is the factor that is the most trainable and crucial during the throw. In the scientific sense, this gives researchers the opportunity to determine the real significance of this element during the throw. In a practical sense, this article gives basketball trainers knowledge about important elements when planning and conducting shooting training.

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