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Review paper

SQUAT – RULES OF PERFORMING AND MOST COMMON MISTAKES

Squat – methodology of teaching

DARIUSZ CZAPROWSKI[1], RYSZARD BIERNAT[1], AGNIESZKA KĘDRA[2]

[1] *Jozef Rusiecki University College in Olsztyn, Faculty of Physiotherapy*
[2] *The Josef Pilsudski University of Physical Education in Warsaw, Faculty of Physical Education and Sport in Biała Podlaska, Department of Posture Correction*

Mailing address: Dariusz Czaprowski, Jozef Rusiecki University College, Faculty of Physiotherapy, 33 Bydgoska Street, 10-243 Olsztyn, tel.: +48 607307773, fax: +48 89 5260400, e-mail: dariusz.czaprowski@interia.pl

Abstract
The squat is an exercise which is commonly applied in sport, recreation and while performing numerous everyday activities [1, 2, 3]. The improper performance of the squat leads to the shaping of an improper movement pattern.
In this work the methodology of teaching the squat, which has to be learnt to constitute a significant element in the prophylaxis of the musculoskeletal system overloads, is described.

Key words: squat, methodology of teaching, mistakes

Introduction

The squat is an exercise which is commonly applied in sport, recreation and while performing numerous everyday activities [1, 2, 3]. A properly performed squat may serve as a basis for the prevention of musculoskeletal system injuries which occur during physical activities. It makes it possible to shape, strength and power harmoniously. Additionally, it positively influences the running speed and improves the height and length of a jump [4, 5, 6, 7, 8]. On the other hand, an improper performance of this exercise may lead to numerous disorders in the musculoskeletal system [6, 9, 10]. For instance, an increase in shearing and compressive forces affecting knee joints may lead to the overload and, as a result, to the injury of cruciate ligaments or to faster degeneration changes in femoropatellar joints [1, 6].

Although the methodology of teaching the squat is simple to learn and people doing sport professionally and recreationally are able to learn the rules of performing it within 10 minutes, the level of knowledge concerning the methodology of teaching the squat is low [3]. The review of Polish scientific and methodological journals done by the authors of this work indicates the lack of systematised methodological cues in this field.

An optimally performed squat is characterised by a proper behaviour of joints (i.e. ankle joint, hip joint and thoracic spine are mobile, while feet, knee joints and lumbar spine are stable), proper coordination of lower extremities muscles and trunk muscles as well as by holding a proper body posture [10]. It should also be accompanied by the lack of pain and discomfort [11]. An improper performance of the squat also leads to the balance disorder and to limiting a proper support of joints by muscles. Repeating this action regularly brings about the consolidation of the bad habit in the nervous system, which, in turn, leads to the shaping of an improper movement pattern [12, 13].

The aim of the work was to discuss the methodological principles of teaching a proper squat on the basis of literature and to indicate the most common mistakes made during its performance.

The methodology of teaching the squat

Stage I – hip hinge
One of the most commonly encountered strategies of performing the squat is beginning the movement with bending the knee joints [10]. The dominance of these joints during the squat leads to an increase in moments of both shearing and compressive forces [10, 14]. Therefore, the process of teaching should be commenced from re-education aimed at reshaping a habit of beginning the squat from a hip hinge [15]. It is done by performing a movement only in this joint accompanied by moving the body mass backward and leaning the trunk forward (which should not be mistaken for a bend forward). It is significant to sustain natural curvatures of the spine during this movement (Fig. 1). A neutral and stable lumbar segment and a slightly straightened thoracic segment serve as the best guarantee of minimising excessive shearing and compressive forces influencing the spine and are, at the same time, the basis for building a proper squat pattern [10, 14, 15].

In order to facilitate the control over the neutral position of the spine, a gymnastic stick which should be in a constant contact with only three points, i.e. sacral bone, peak of the thoracic kyphosis and occiput, can be used [6, 15].

The aim of this exercise is to transfer the movement from the knee joints which are frequently improperly engaged during the squat. This movement improves muscle strength, body awareness. In the case of performing it on one leg, it makes it possible to detect and reduce the right-left asymmetry. Hip hinge improves the stabilisation of the trunk, strengthens the middle and greatest gluteal muscles and assures a functional mobility of the hip joints. What is significant is the fact that this movement triggers the activation of muscles of both local and global stabilisation systems. An efficient isolated movement in the hip joints protects the spine and knee joints [6, 10, 14, 15].

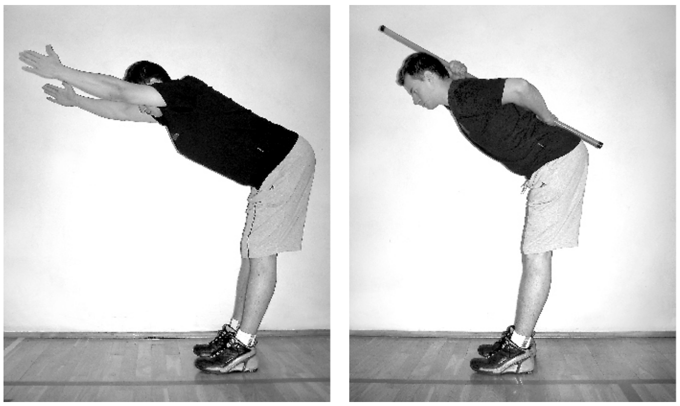

Figure 1. Hip hinge

People with a higher level of physical skills or those who have already learnt the above exercise should proceed to performing it on one leg with the accompanying movement of the upper extremities (Fig. 2). A more difficult option of this exercise involves performing it on one lower extremity with the accompanying movement of the opposite upper extremity. It should be held straight in an elbow joint and sustained in the intermediate position between internal and external rotation. A shoulder blade should be held in a neutral position. During the exercise pelvis rotation should be avoided. Additionally, a load held in one or both hands can be used. In the first case the exercise will be oriented more at the development of strength. When the load is held in one hand, mostly stabilisation will be shaped due to the fact that rotation force triggered by an external load (i.e. kettle-bells, dumbbells, bar) is resisted [2, 15]. The ability of performing a hip hinge properly both on two and on one leg is the introduction to implementing a controlled bend and extension in the knee joints. However, it should be remembered that the hip joints play an initiating role in this movement [6, 10].

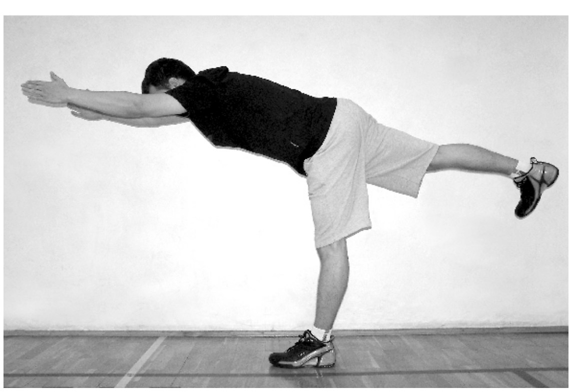

Figure 2. Hip hinge on one leg

In the first phase of learning a limited number of 5 to 7 repetitions should be applied. What is equally important, is the pace of performing the squat. A fast pace (1/1 – the movement of both lowering and raising the body mass centre lasts one second each) brings about a 30% increase in shearing forces compared to a slow pace (2/2). Therefore, a slow controlled pace is recommended for the protection of cruciate ligaments. From the practical point of view, it is also significant that tiredness brings about an increase in both shearing and compressive forces by 25-85% from the first repetition to the last one [6, 10, 14].

Stage II – a proper squat

Mastering a proper movement in hip joints is the basis for moving to the second stage. Its aim is to learn a proper squat which is characterised by the following features (Fig. 3) [3, 6, 14, 16]:

- feet set parallel (optionally with a maximum 7-10° abduction in the ankle joints) at the width of shoulders, heels touching the floor;
- knee joints set in one line between the hips and feet;
- hip joints bent and shifted backwards;
- lumbar segment of the spine held in a neutral position;
- thoracic segment of the spine slightly straightened or in a neutral position;
- constant inclination of the trunk in every phase of the squat;
- head held in a neutral position (gaze directed straight ahead or slightly upwards);
- optimal depth of the squat: the knee joints bend angle – 90°;
- maximum depth of the squat should fit between 115-125° (thighs parallel to the floor).

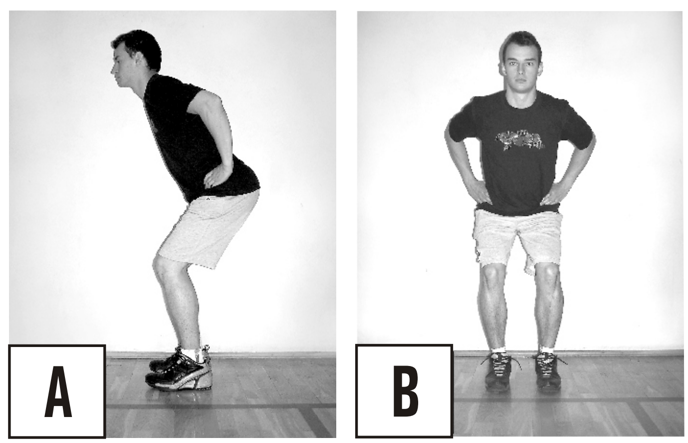

Figure 3. A properly performed squat. A – view in the sagittal plane, B – view in the coronal plane

The ability to perform a proper squat on both legs is the introduction to learning a one-leg squat with sustaining all the aforementioned features. Such the squat is particularly significant in the case of people practising sport professionally and people performing recreational physical activity since it ensures a proper activity of the muscles, stabilising a lower extremity and makes it possible to detect and reduce the right/left asymmetry [2, 17, 18].

Stage III – functional exercises with the use of a proper squat

Having mastered the squat with a marked dominance of hip joints and holding a proper position of the lower extremities, the trunk and the head in all planes, one should proceed to learning to perform the exercises at a fast pace. The exercises are often aimed at specific physical skills useful in particular sports [6, 9, 10, 17]. At this stage the level of difficulty of the exercises performed is raised gradually by introducing, inter alia, an unstable surface and exercises with the change in the direction of movement [6, 9, 14, 19]. Examples of such exercises are presented in Figures 4, 5, 6.

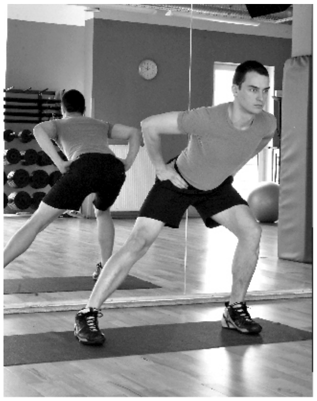

Figure 4. A side lunge with sustaining a proper control over the squat

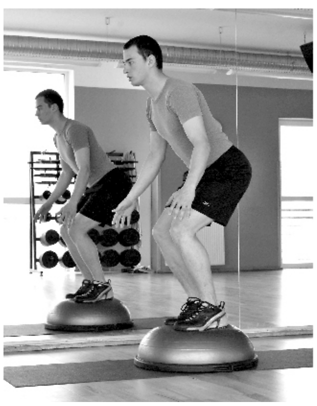

Figure 5. A squat on an unstable surface – BOSU

Figure 6. A proper performance of the squat and landing with the use of an unstable surface

Mistakes while performing the squat

The squat is one of the most commonly used forms of exercise. Unfortunately, while performing it, a range of irregularities may occur. The most frequently occurring irregularities may include the following:

- setting feet broader than the width of the shoulders. The consequence of such a position of the feet is an increase in the activity of the hip joints adductors. It leads to an increase in the moments of force affecting the knee and hip joints [20, 21];
- raising the heels during the squat. It is frequently caused by the shortening of a soleus muscle, which leads to a limited dorsiflexion. As a consequence, the knee joints lose stability, which leads to the fact that they are shifted forward behind the line of the toes [10, 13]. It brings about the overload on these joints but also on the hip joints and on the lumbar segment of the spine [7, 8, 22] (Fig. 7);

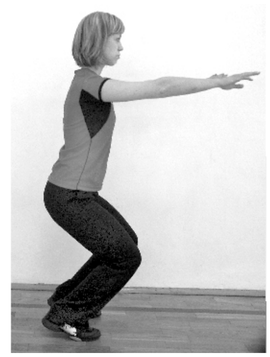

Figure 7. A typical improperly performed squat

- the inability to hold an axis hip/knee/foot – varus or valgus knees. It is usually caused by the disorders in the muscles stabilising the pelvic girdle in the coronal plane – with a particular consideration of the weakening of a middle gluteal muscle. It leads to an increase in shearing forces causing the overload on anterior, posterior and collateral cruciate ligaments [5, 18, 23] (Fig. 8, 9);

Figure 8. A squat performed without the control over the axis of the lower extremities

Figure 9. A no reverse position

- no control over the position of the knee joints in the sagittal plane – their excessive shift forward behind the line of the toes. As a result, anterior shearing and compressive forces are increased. An excessive shift of the knees backwards leads, in turn, to the trunk inclination and an increase in shearing forces in the lumbar segment of the spine. With regard to this, it is presently recommended to shift the joints a few centimetres before the line of the toes [1] (Fig. 10);

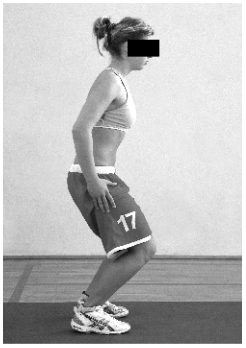

Figure 10. No control over the position of the knee joints in the sagittal plane during the squat (the figure also shows an improper backward shift of the pelvis)

- beginning the squat from the movement in the knee joints, which leads to an increase in the activity of the quadriceps muscles of the thighs with a simultaneous decrease in the activity of the hip joints extensor [24];
- an excessively dynamic way of performing a full squat causing the contact of the back surface of the thigh with the calf muscles. It leads to the shift of a rotation axis in the knee joint backwards and the occurrence of dislocation forces as well as an excessive stretch of the anterior cruciate ligament [2];
- no control over a neutral position of the lumbar segment of the spine. A typical, improper strategy during the squat is a backward inclination of the pelvis and a bend in the lumbar segment of the spine which allows for a bigger bend in the hip joints. However, this pattern leads to the quietening of the back extensors and the occurrence of shearing forces. In turn, the squat with an excessively straightened lumbar segment of the spine causes a significant increase in compressive forces [2, 24, 25];
- no control over a neutral or slightly straightened position of the thoracic segment of the spine (deeper thoracic kyphosis during the squat), which leads to an increase in shearing and compressive forces, especially when at the same time the lumbar spine is not in a neutral position, i.e. in an excessive extension or bend. It is one of the most common improper patterns [12, 13] (Fig. 11);

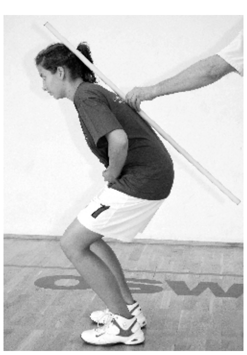

Figure 11. No control over the thoracic and lumbar segment of the spine during the squat

- an inability to sustain a constant trunk inclination angle in every phase of the squat, which indicates the lack of control and stability of the lumbar segment of the spine [10, 13, 24];
- a cervical segment bend with the head inclination leading to a deeper thoracic kyphosis [2, 26].

Willson et al. [18] indicate the so-called no reverse position which is characterised by the adduction and internal rotation of a hip joint, abduction of a knee joint, dynamic knee valgity, external rotation of a calf and foot eversion (Fig. 9), and which results from the disorders in the control of the stabilisation of the ilio-pelvic complex, especially in the coronal plane. It results in the overloads on the musculoskeletal system which lead to its injuries [1, 2, 10, 12, 13].

One of the most frequent injuries in both professional and amateur sport is the injury of the knee ligaments [27]. The tension of a posterior cruciate ligament (PCL) during the squat increases with the angle of the knee joint bend. The force affecting the PCL occurs in the angle over 60° when the quadriceps muscle induces a posterior shearing force. However, the level of this force is low and does not pose a risk to a healthy PCL. Nonetheless, if the ligament is injured the squat should be limited to about 60° bend in a knee joint [1, 6].

Additionally, forces affecting the anterior cruciate ligament (ACL) are generated in the angles of 0°-60°. However, these forces are not high and most often do not exceed 500 N, which at a maximum load on an ACL equal to 2000 N brings about the fact that the squat is a completely safe exercise even for people with a ligament injury [1, 6].

From a prophylactic point of view, it is significant that the shearing forces occurring during the squat are opposed by the activity of posterior thigh muscles. It can be achieved by cocontraction, i.e. by applying a proper pattern of the squat based on beginning the movement from bending the hip joints shifting them at the same time backwards with the simultaneous inclination of the trunk forward [15]. An eccentric role of these muscles is bigger than their concentric role and their activity reaches a maximum value at the angle of the knee joints bend equal to 120°. In practice, this angle may be defined by a parallel position of the thighs towards the ground [28]. The peak activity of a quadriceps muscle occurs at the 90° bend in the knee joints without a further growth at higher values of the bends. Therefore, a half-squat up to 90° is an optimal depth of the squat [28].

Conclusions

A properly performed squat is a significant element of the prophylaxis of the musculoskeletal system overloads. It refers both to professional athletes and to people doing amateur sports. It is also used by people who do not do any physical activity. It can be observed, for instance, while carrying or lifting objects and at work. However, taking into consideration the aforementioned possibilities of making a mistake while performing it and risks of overloading a musculoskeletal system connected with it, it is significant to learn a proper methodology of teaching the squat by people associated with physical activities, i.e. physical education teachers, physiotherapists or coaches. It is also significant to indicate the most common mistakes made during the squat and threats for the musculoskeletal system connected with it. According to Liebenson [19], the majority of back pains result from an improper way of lifting objects from the ground resulting from an improper squat. Additionally, as Cook [10], Kendall et al. [12] and Sahrmann [13] claim, its proper performance provides a person exercising with benefits and constitutes a significant element of health prophylaxis.

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