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Review article

POSSIBILITIES OF USING NEUROCOME BALANCE MASTER PLATFORM FOR BALANCE ASSESSMENT AFTER KNEE INJURY

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Abstract: Due to its complex and fine structure, the knee joint is less resistant to the influence of external factors, which is why knee injuries often occur in sports. Knee joint injuries lead to mechanical and functional instability. Lately there have been significant innovative advancements in diagnostics, inoperative and surgical treatment of knee injuries and diseases. Technological progress has enabled objective assessment by means of computerized techniques, namely kinesiometric platforms. The possibilities of using such systems in sports are of high importance, especially in assessments of injuries, in evaluation and comparison of treatments, but also in forecasting lower limb injuries and the potential risk of falling down.

The aim of this paper is to conduct a review of the research based on the insight in the available literature, where NeuroCom Balance Master kinesiometric platform was used as the research instrument, and to determine the possibility of its clinical application on knee joint injury.

The available literature was reviewed by insight into electronic databases (EBSCO Medline, EBSCO host, ScienceDirekt, ProQuest), which are

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available via the Serbian Library Consortium for Coordinated Acquisition (KoBSon).

Key words: *injury, postural stability, balance assessment, Neurocom Balance Master*

INTRODUCTION

The function of the lower limbs is to carry and support the weight of the body while standing, walking, running and carrying weight in daily, professional and sports activities. In fact, lower limbs are more exposed to injuries than the upper limbs. In sports, knee and ankle joint are most exposed to injuries. Due to its complexity and fine structure, the knee joint is unprotected and poorly resistant to exogenous factors. To the present day, anatomical shape and structure of knee joints remains the subject of the most intensive morphological research and biomechanical studies.

Knee joint injuries are common in young persons and they lead to mechanical and functional instability. Anterior cruciate ligament (ACL) injury is the most common one and makes 50% of all knee injuries. It occurs in healthy and physically active persons, especially in sportsmen. Apart from the acute symptoms, pain and swelling, this is an injury which leads to a rotational instability of the knee and which hinders lower limb function (Nakamuta et al., 2011). ACL injury incidence among the population is 32 to 70 in 100,000 people annually, while in sportsmen, especially soccer players, this number ranges from 500 to 8500 (Walden et al., 2011). Apart from the anterior cruciate ligament injury, injuries of other ligaments and soft structures also occur often, as well as meniscus injuries, knee subluxation and dislocation and patellar fractures.

Technological progress has enabled objective assessment by means of computerized techniques, namely kinesiometric platforms. The possibilities of using such systems in sports are of a high importance, especially in assessments on injuries, in the evaluation and comparison of treatments, but also in forecasting lower limb injuries and the potential risk of falling down.

After knee joint injury, the main goal of rehabilitation is the improvement of dynamic stability and function recovery. Lately there have been significant innovative advancements in diagnostics, inoperative and surgical treatment of knee injuries and diseases. At the same time, the methodology of functional diagnostics, physical therapy, kinesiotherapy and rehabilitation has been developed. Rehabilitation implies a quick and precise knee functionality assessment and application of an appropriate treatment.

Knee injury clinical evaluation includes injury history data and physical examination, which reveals a functional integrity of the injured structures. The physical examination of the knee begins with observation and analysis of static and dynamic posture and recognizing gait abnormalities and asymmetry. Subjective and objective assessments can be used to assess postural stability (balance) on knee injury. Subjective postural stability assessment implies static and dynamic balance testing by using standardized tests such as the *single-leg balance test* (Ross et al., 2008), the *Star Excursion Balance Test* (Riemann & Schmitz, 2012), and the *Multiple Single-Leg Hope Stabilization Test* (Riemann et al., 1999), etc.

Technological progress has enabled an objective assessment of balance by means of computerized techniques, namely kinesiometric platforms. These systems provide an easy and practical method for a quantitative assessment of balance through postural sway analysis (Guskiewicz & Perrin 1996). The possibilities of using such systems in sports are of a high importance, especially in the assessments on injuries, in evaluation and comparison of treatments, but also in forecasting lower limb injuries and the potential risk of falling down. The following systems are often used for the purpose of objective static stability assessment: Chattecx Balance System, Force Plate, Pro Balance Master, and Smart Balance Master. For dynamic stability testing, Biodex Stability System, Chattecx Balance System, Kinesthetic Ability Trainer and Neurocom Balance Master are being used.

N*eurocom Balance Master kinesiometric platform* has developed sophisticated systems with expanded diagnostics and options for postural stability improvement training. It enables an objective registration of data on the existence of sensory and motor dysfunctions, monitoring parameters and constantly showing the body balance point projection by means of cursors, on the screen. The kinesiometric platform consists of the following elements: a software system, sensory platform, auxiliary wooden and sponge elements and protective railing. Sensors installed in the platform register and measure the intensity of vertical forces, transmitted through feet. The platform provides particularly precise results in the subjects whose mass is between 18 and 136 kg. A computerized analysis of the functional balance control of the subject is based on the application of a wide range of tests, in standing and sitting positions. Upon testing, the results are shown graphically and numerically. The platform also provides sensory and voluntary motor control of stability, including visual feedback. The basic set of tests includes: Modified Clinical Test of Sensory Interaction on Balance (*mCTSIB*); Unilateral Stance (*US*); Limits of stability (*LOS*); Rhythmic Weight Shift (*RWS*); Step Quick Turn (*SQT*); Tandem Walk (*TW*) as well as the Walk Across (*WA*) test (NeuroCom International Inc).

RESEARCH OVERVIEW

In the post knee injury rehabilitation of sportsmen, especially of the anterior cruciate ligament, apart from the assessment of the ankle strength and mobility, attention is increasingly paid to proprioception (Lephard et at., 1997). Changes in proprioception may occur due to ACL injury and mechanoreceptor damage within the ligaments, and as a consequence, the function of an afferent impulse transmitting function can be reduced or lost. In addition, receptors within muscles can cause changes in proprioception after injuries (Kennedy et al., 1892). Thus, in knee joint functionality assessment, it is important to assess the postural stability in addition to muscle strength and mobility. The Neurocom Balance Master kinesiometric platform can be used for such purpose.

For example, in their research, Chmielewski and associates (2002) used the platform in a clinical assessment of individuals aged 25 in average, upon surgical treatment of an ACL injury. The subjects were divided into three groups. The first control group, consisted of 85 subjects (44 men and 41 women) who had no injuries or diseases of the lower back or lower limbs in their anamnesis. The other, experimental group consisted of 10 subjects (7 men and 3 women) with a complete single-sided rupture (confirmed by magnetic resonance imaging) of the anterior cruciate ligament (ACLD group), classified as a group of subjects with unstable knees. The third group (ACLR) consisted of 10 subjects (2 men and 8 women), who underwent a surgical ligament reconstruction, and all subjects had physical therapy upon reconstruction. The testing was conducted upon first, sixth and twelfth weeks postoperatively.

In order to assess postural stability (the balance), the authors used four tests of the *Neurocom Balance Master* platform. The first test used was *Weight Bearing Squat (WBS).* The subjects were asked to equally distribute their weight to both legs, while standing upright in several different knee positions. Leg stress assessment (expressed in percentages) was measured with the knees in the default position 0° (straight knees), then in the position with the knees bent at 30°, 60° and 90° angles. After each attempt, the subjects had a 10-second break. In the upright standing position, knees and hips were relatively unstressed. By increasing the squat depth, the stress on the knees and hips increased, making these positions much more sensitive for discovery of support abnormalities in musculoskeletal changes of lower limbs. The percentage of weight supported by the leg in use was expressed numerically, and the measured parameters were given for each leg and each position separately.

The other test which was used in this research was *Unilateral Stance (US)*, which supports the velocity of a postural sway when a subject stands on the right or the left foot, with his/her eyes open. The subjects were instructed to bend the tested leg in the knee by 20°, and then to attempt at the request of the researcher to transfer their weight to it and maintain their balance without holding on to something. The duration of each attempt amounted to 10 seconds, and the subjects repeated the test three times for each leg, making a 10-second pause between the attempts. The observed parameter in this test was the *Mean COG Sway Velocity* which shows the stability of the balance point while the subjects stands independently on each leg with his/her eyes open, expressed in degrees per second (deg/sec).

The position change test *Sit to Stand test (STS)* was used by the authors to assess balance point movement control during the change from a sitting to a standing position. The subjects were instructed to stand up from the sitting position and to maintain a standing position (10 seconds in the control group and 30 seconds in the experimental group). The subjects sat on a wooden bench with felt pads, from 100° in the knees and 90° in the hip, with the weight equally distributed to both legs. The observed parameters in this test were the *Rising Index (RI)* measured as percentage, which represents the force exerted by the legs at the standing-up stage and *Cog Sway Velocity (CSV)* – control of the balance point above the support base during the transfer, as well as 10 and 30 afterwards, expressed in degrees per second (deg/sec). The subjects repeated the test three times.

The fourth test the authors performed was the S*tep Up/Over (SUO)* test. This test determines the characteristics of motor control when stepping on the obstacle with a single foot, followed by the raising of the body, assuming and maintaining the upright posture on the obstacle, putting the other leg over the obstacle and finally lowering the body by supporting the other foot against the surface. For the purpose of this test, the authors used a 30 cm high wooden bench and remaining in the position after a leap of 5 seconds. The subjects repeated the test three times, with a 10 second break between each attempt. The two parameters were assessed in this test, namely the *Movement Time* (the time necessary for performing the manoeuvre measured in seconds, starting from the initial raising of the posterior leg from the surface and ending with the contact made by that same foot with the surface in front of the obstacle) and *Impact Index* (the maximum vertical impact on the contact of the free leg with the surface, expressed as a percentage of body weight).

In addition to assessing postural stability, the study also included the test of maximum voluntary isometric contractions (*MVIC test*) for the assessment of muscle strength (of *quadriceps femoris*) and two scales for the self-assessment of functionality during the performance of daily activities (The Activities of Daily Living Scale (ADLS) and the Global Rating scale).

The main hypothesis of this research refers to the changes in the assessed parameters of postural stability in relation to the muscle strength of the *quadriceps femoris* muscle and the applied scales for functionality self-assessment. The *WBS* test showed a statistically significant correlation between muscle strength and the load on the injured leg (at 90° knee flexion) in the first week following surgery in the third group of subjects. However, in the sixth week following surgery, the weight was symmetrically distributed to both legs in this group, hence the findings lost their clinical significance in this test. The *ULS* test determined significant changes in the postural sway in the group with unstable knees, while the third group was not significantly different from the healthy subjects. In the third group, using the *SUO* test, the authors determined a significant correlation between the declined strength of the four-headed thigh muscle and the time necessary to perform a leap in the first week of testing, while the speed of the leap significantly improved in the second series of tests (6 weeks later) with the improved muscle strength.

In conclusion, the authors emphasised the statistically significant correlation between muscle strength and some of the assessed variables of postural stability. The differences between the second and the third group were identified in the weight-bearing squat test 6 weeks following the reconstruction, but no correlation was found with the functionality scales, whereas the *Step Up/Over tes*t proved clinically useful as it established a correlation with the assessed scales.

The stability of the knee joint depends on the interaction between bone structures, soft tissue, body weight and muscle strength. While the bone structure and the characteristics of the meniscus do not provide a high degree of stability, the soft knee structures (ligaments, capsule) contribute to maintaining balance. When high-intensity physical activity is practiced, muscle strength stabilizing the knee joint and preventing ligament overload are essential to postural stability (Williams et al., 2001). Therefore, in 2009 Moussa et al. undertook to assess postural stability in persons two years following the reconstruction of the anterior cruciate ligament. The research involved 26 football players (the first group) at the average age of 22 who had undergone unilateral ligament reconstruction. The control group was comprised of 20 healthy individuals of similar age. All subjects in the first group had undergone the same reconstruction and had returned to their activities afterwards. On average, all subjects were tested 2 years following the reconstruction.

The criteria for participating in the study were the following: a single surgical procedure without any damage to collateral ligaments, no previous injury to the ankle joint or the hip, a full return to one's activities and no reports of instability. Postural stability was assessed using the *Neurocom Balance Master* platform and a single-leg hop test was used. The *US* single leg support was applied. This test quantifies the velocity of postural sway during unilateral stance. A relative absence of a sway in a still position indicates better stability. Standing on a single leg was assessed in both legs under two conditions: with a fully extended knee and with the knee bent at 20°. The subjects repeated the test three times with a one minute break apart. The postural sway (deg/sec) was shown for each leg individually. A statistically significant difference was established between the first and the second group ($p<0.05$) in circumstances when the knee was fully extended on the side where the reconstruction was performed. The authors' main conclusion was that two years following reconstruction of the anterior cruciate ligament the subjects experienced a change in postural stability. The analysis of the single-leg hop test failed to show any differences between the groups. Two years following reconstruction, the subjects' postural stability was significantly worse in the operated limb when the *Neurocom Balance Master* platform was used for stability assessment. There was a significant asymmetry between the dominant and the non-dominant leg, with postural sway assessment using the platform proving to be an efficient method for measuring postural control in individuals after the reconstruction of the anterior cruciate ligament (ACL).

The application of autologous chondrocytes implantation (ACI) in the therapy of damage to the knee joint cartilage proved an effective procedure compared to traditional chondroplasty. Howard et al. (2014) tried to document the recovery of the function in individuals after the application of ACI. The research included 48 subjects with the average age of 35. All subjects had undergone implantation, and followed the standard recovery protocol during the rehabilitation period. In the first two weeks following the intervention, the subjects were not allowed any support, during which period the leg was immobilized in a fully extended position. After two weeks, support was gradually introduced to the subjects and mobility of the joint was allowed, while all of them were advised to refrain from high-intensity physical activity in the first 12 months following the procedure. For the purpose of functional assessment, the authors used scales for self-assessment of the function (SF-36 PCS, Western Ontario and McMaster Osteoarthritis Index, the International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form and the Lysholm scale). Postural stability was assessed using the *Neurocom Balance Master* platform. For balance assessment, the authors used the *WBS test, Walk Across test, STS test, SUO test* and the *Forward lunge (FL) test*. The subjects were tested before surgery, and then 3, 6 and 12 months following the procedure. The assessment was performed by the same examiner, and the healthy leg was always tested first.

For the weight bearing squat (*WBS*) test, different knee positions were assumed (0°, 30°, 60° and 90°). In the *WA* test, the subjects were instructed to walk along the entire length of the platform, following their own rhythm and pace. This test assesses the characteristics of a walk by moving across the sensory platform. The parameters to be determined are the average width and length of a step, and the speed of momentum measured by the speed of establishing the touching point with the surface. For the *STS* test the subjects sat on a 50 cm high wooden bench and were instructed to stand up as soon as possible and remain 10 seconds in the standing-up position. For assessing the characteristics of motor control during the *SUO* test, a wooden bench 30 cm high was used. The assessment of body movement while lunging on one leg was measured by the *FL* test.

The change was recorded in all subjects over time. The *WBS* test returned not so significant, but nevertheless, lower values of shifting the weight onto the operated leg at given knee flexion angles over the period of one year. Statistically significant difference was determined on the *WA* test, where the length of the step increased, comparing the situation before and after the procedure in the first year. The *STS* test showed the earliest positive effects of the procedure in terms of a shorter time of shifting the centre of gravity in the first three months. The time continued to decrease gradually even after 6 and 12 months following the procedure. Analysing the *SUO* test results and the parameters of the *Lift–Up Index* which determines the maximum force of lifting the leading leg and is expressed in the percentage of the individual's total body weight, a significant index increase was identified in the first year. Finally, the *FL* test established the increase of the *Impact index* (maximum vertical contraction exercised by the leg stepping forward on the basis of the support, expressed in the percentage of body weight) which gradually increased over time.

The main aim of this study was to predict the recovery time after the implantation of autologous chondrocytes in the damaged cartilage of the knee joint, so as to obtain data which could be significant for both doctors and patients. Based on the results, the authors concluded that in the first few months, the symptoms such as pain had decreased although the functional recovery of the knee and the possibility to improve postural stability takes 12 months or possibly longer. The authors reached this conclusion through precise measurements using computerized equipment – the kinesiometric platform *Neurocom Balance Master.*

CONCLUSION

Neurocom Balance Master platform has eleven tests for assessing static and dynamic postural stability, the most commonly used tests for balance assessment after knee joint injury being the unilateral stance (*US*) test, the weight bearing squat (*WBS*) test, the Step up/Over (*SUO*) test and the Forward Lunge (*FL*) test.

Neurocom Balance Master allows the objective assessment of sensory and voluntary motor control of balance with the presence of visual feedback. The platform has a possibility for assessing and treating all elements of postural stability. In sport, it is a screening method for monitoring athletes after injuries or surgery. It is useful for determining the progression of treatment and assessing the athletes for returning to their physical activities.

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