DETERMINING THE FUNCTIONAL SYMMETRY OF THE LOWER LIMBS BY USING THE Y BALANCE TEST

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Abstract. *The Y Balance Test is a dynamic test performed in a single-leg balance position that requires strength and mobility. The test is used to assess the functional symmetry of the lower limbs and identify athletes at high risk of injury. Technological advances in equipment and slope preparation as well as the increase in strength and speed indices have turned alpine skiing into an extremely spectacular sport, which is why the stress on athletes' muscles and joints has constantly grown. Therefore, permanent changes in non-specific training have been required in recent times, leading coaches to be more and more concerned with finding the most effective methods of training and preventing injuries. In order to make training performance more efficient, calculation formulas are used to identify differences in limb symmetry. The research purpose was to identify the most effective methods and means leading to the development of joint mobility and the prevention of injuries. The research consisted of a case study that was conducted over eight weeks and included training programmes for the development of both mobility and specific speed and strength. The research was carried out experimentally so that the results obtained could be implemented in the future training programmes of the national team. The participant belongs to the Carpați Sinaia Sports Club and was assessed by the Y Balance Test. The athlete's results in the final test highlighted the effectiveness of the training programmes, which was revealed by an increase in the composite score between the two tests.*

Keywords: *Y Balance Test, alpine skiing, non-specific training.*

Introduction

The Y Balance Test was developed to refine the long process involved by the performance of the Star Excursion Balance Test. Therefore, most of the supporting research for the Y Balance Test was based on the investigations conducted on the Star Excursion Balance Test. The Y Balance Test has been proven to have a high level of test-retest reliability and to be a sensitive indicator of injury risk among athletes. (Walker, 2016)

Previous research (Plisky et al., 2006; Šiupšinskas et al., 2019; Chimera & Warren, 2016) has suggested that poor dynamic balance may be associated with an increased risk of injury in athletes; even so, this issue has not yet been examined in Romanian alpine skiers. Alpine skiing, also called downhill skiing, has become an extremely spectacular sport due to the way the slopes are prepared for competitions and the very hard materials used. This leads to changes in the training of athletes, who are required to increase their performance and maintain their health. Lower limb mobility helps the skier to perform movements with an appropriate (see optimal) range of motion in each of the joints involved. Muscle elasticity mainly influences competition performance in an indirect way, in the sense that shortened muscles quickly cause muscle imbalances, which leads to sensitisation and an increased risk of injury (Hrysomallis, 2007). Muscles should not be trained separately but should stimulate the motor skills specific to each sport (Bompa & Carrera, 2005). In alpine skiing, dynamic

balance is achieved through swinging movements on spaces as small as possible. Body inclination towards the inside of the turn must be performed at a correct angle, and pressure distribution on the skis must be done accordingly (Raschner et al., 2017). From this point of view, determining the functional symmetry of the lower limbs in skiers becomes extremely important. As an integral part of functional movement systems, the Y Balance Test is a way to assess functional symmetry and dynamic balance in athletes and predict their risk of injury.

The functional conditions of the muscle system, namely strength and mobility, must be tested on a regular basis. The objective of performance diagnosis is to determine the athletes' performance capacity in order to compare and establish the specificities of their individual training (Răchită et al., 2019). If performance is diagnosed at regular intervals, it is possible to check the effectiveness of the measures taken regarding the proper development of the training and also to plan its future content (load, volume, intensity) at an optimal level. To check the athletes' efficiency in motor terms, the observation method used by the coach and periodic testing are especially important. Systematic observation, which is defined "as a particular approach to quantifying behavior" (Bakeman & Gottman, 1997, p. 3), provides important data on athletes' progress during training in accordance with the proposed objectives. Tests are effective and conclusive only when the results can be compared with each other, e.g., performance monitoring before and after the end of a training cycle.

Training for general muscle development and stress on certain muscle groups during on-snow training require extra work on mobility to avoid muscle tears and contractions or any imbalances that may occur.

Alpine skiers show great deficits in the development of their posterior thigh muscles (knee flexors), which can be detected through regular functional tests and removed through appropriate training precisely focused on this muscle group. In addition to general mobility, the elasticity of specific muscle groups involved in downhill skiing must also be maintained. Thus, performing movements with an adequate range of motion in each of the joints concerned plays a decisive role in achieving maximum efficiency in both training and competition. Range of motion is limited by joint mobility and muscle elasticity. Static stretching and extension methods are very good for maintaining elasticity and regenerating muscles after strenuous training sessions.

The objectives of non-specific training for elite alpine skiers are to increase performance capacity and maintain physical health. On-snow training should primarily aim at developing and consolidating the technique. For this purpose, all the requirements of proper physical training must be met. The high technical level in alpine skiing is the expression of the specific physical qualities of an athlete, which is why all muscle imbalances that may occur as a result of poor technique must be eliminated.

These imbalances often occur in the thigh muscles if the contracting muscles of the leg are too weak compared to the extensors, therefore there is too many pressure and stress on the knee joint (ligaments, meniscus, patella, cartilage), which leads to injury. Muscle imbalances contribute to the unequal participation of muscles in motor actions. Improper and superficial training causes imbalances in both muscles and joints. The consequences appear in the mechanics of the joints, the unequal distribution of muscle pressure and stress, the limitation of limb movement, compensatory hypermobility, changes in proprioceptive stimuli and motor stereotypes. For these reasons, a gradual, consistent and long-term increase in physical

exertion is imperative during training. Therefore, athletes need constant supervision and monitoring of their bodies' response to exercise. Thus, tests can provide coaches with useful information for establishing individual training plans. (Leonte et al., 2020)

All skills and actions are performed by the muscles as a result of contractions. Muscles and joints are able to perform a wide range of movements. When the purpose is to improve a skill or performance in a certain direction, the focus will be on training the muscles involved in that action but also joint mobility and primary effector muscles. The process of prescribing exercises for one or more muscle groups must be based on training-specific arguments. In the anatomical adaptation phase, the chosen exercises must develop the majority of agonist and antagonist muscle groups along with joint mobility in order to build a solid foundation for the training stages. This is done by analysing skill performance, angle direction or limb position. Primary effector muscles responsible for skill performance will be determined, and this step will be followed by the selection of exercises involving these muscles and joints based on the similarity contraction. Exercises should involve the muscles and joints in an order similar to that used to perform a skill.

In alpine skiing, dynamic balance plays a major role in consolidating the technique, primarily through the development of the neuromuscular system that ensures joint stability and mobility. Balance is affected when imbalances occur in the mobility and flexibility of the limbs or joints. Postural instability can lead to falls or uncontrolled movements that increase the risk of injury. The Y Balance Test is a reliable test for assessing dynamic balance and lower limb mobility.

Problem statement

The Y Balance Test was used in this study to determine the functional symmetry of the lower limbs. The balance testing protocol was developed during many years of research so as to improve performance and prevent injuries. The Y Balance Test requires the athlete to maintain balance on one leg while the other leg simultaneously reaches as far as possible in three directions: anterior, posterolateral and posteromedial. The athlete must then do the same with the other leg, meaning that six tests need to be performed. The score is calculated by summing the three reach directions and normalising the results to lower limb length in order to determine the "composite reach distance". Asymmetry is calculated by the difference between right and left limb reach. (Walker, 2016)

The case study proposed in the present research aims to complement physical training and contribute to injury prevention.

In alpine skiing, on-snow training is the central point, but it is complemented by dry-land training, with both of them planned so as to ensure the prevention of injuries. Thus, non-specific training plays a decisive role in achieving sports results. The training performance of athletes after the tests allows the coach to develop training plans that will help them to be physically prepared and eliminate the risk of injury.

Prescriptions are used to schedule training sessions as well as to design and plan activities (preparing perspective plans on Olympic cycles, annual plans, stage plans, microcycles and training plans) (Tudor et al., 2013).

Most training programmes place too much emphasis on muscle strengthening and overlook injury prevention. Because the ligament-joint complex can become a limiting factor in training, the adaptation of connective tissue takes several weeks. Therefore, anatomical adaptation training should focus not only on muscle strengthening but also on strengthening connective tissue in order to prevent injuries (Leonte et al., 2019). In this regard, an important element is represented by the flexibility exercises performed at the end of the warm-up during the rest interval after each exercise, as well as during the recovery process.

The joints that need to be exercised during training are specific to the sport practised. Providing flexibility and strength training along with permanent education can prevent many injuries and increase athletes' technical skills. Exercises aimed at strengthening the joints, maintaining optimal body weight and consolidating sport-specific technical and tactical skills should be part of the training programme.

Non-specific physical training in elite alpine skiing acquires particularly important nuances and new directions due to both the hard materials from which the equipment is made and the way the slopes are prepared. The forces acting on the skier during turns, the very hard slopes and the speeds reached place extremely high demands on the skier and require coaches to find the best methods and means of training. Through kinaesthetic differentiation, movements acquire a specific character and are gradually prioritised based on the information received from one's own body, more precisely from muscles, tendons and ligaments. Controlling balance involves maintaining and regaining it in different situations due to the development of strength and flexibility specific to joints and muscles. Thus, the characteristics of coordination in a practical model are three levels of motor stages, namely learning-consolidation, application-variation and creation-completion. The central point of this model is dynamic balance. In the sports technique, coordination features oriented as objectives towards performing movements, in the sense of establishing them as solutions to accomplish sports tasks, are of particular importance and become prerequisites to reach a higher technical level. Coordination and flexibility training is defining to lay the foundations for the specific development of a sport. Non-specific training that includes flexibility can be general, meaning that each component is performed through means aimed at achieving precise motor tasks. Proper physical training focused on building good mobility of the lower limbs helps the athlete to better adapt to the various conditions of the track, better perceive their own body when sliding, better react and adapt to changing snow conditions but also better adapt their pace of movement to the given pace or imposed by establishing the direction of the travel trajectory. Gaining balance is the core of meeting these requirements. Dynamic balance must be permanently achieved on all three levels through swinging movements on spaces as small as possible. For an alpine skier, body inclination towards the inside of the turn must be done at a correct angle in the frontal plane and also a dynamic pendulum movement must be performed (redistribution of the load, namely of the pressure on the skis, front of the foot-heel) in the sagittal plane (front-back). This can only be achieved through very good mobility of the ankle and knee and flexibility of the thigh muscles.

Elite performance involves long-term training and systematic planning. Training demands and objectives must be permanently increased in order to ensure a constant improvement in athletes' performance capacity and implicitly performance level. In alpine skiing, the beginning of the qualitative leap and the achievement of top performance occurs around the

age of 18-20 for girls and between 20 and 22 years for boys. Until these ages, the potential for performance and efficiency must be brought close to the limits of each athlete's individual capabilities. Linkage training should ensure that fitness components are raised to the highest level through balanced muscle groups between the upper and lower body, between the right and left half or the front or back of the limbs.

The endurance capacity of muscles, tendons, ligaments and the skeletal system to external forces can be improved through personalised physical training with an emphasis on strength and joint mobility. Mobility needs to be trained as early as possible in order to reach the required joint elasticity and thus fight in good time the appearance of muscular imbalances. An important element is nerve transmission because the desired strength development depends not only on muscle mass or quality but also on how it is stimulated by the nervous system. The more fibres a muscle can activate simultaneously, the higher its strength. Intermuscular coordination means the interplay of several muscles within a muscle chain (for example, the extensors of the leg, thigh and buttocks) and the entire muscles that contribute to a movement. Mobility, as a component of this type of coordination, explains the enormous importance of complex exercises that simultaneously involve a large number of muscles. When an improvement in lower limb strength is intended but the training only aims at the linear pressure of contraction-stretching of the thigh and leg muscles without taking into account that, due to leg extension during skiing, the heels and torso must be stabilised and that ankle joint mobility is reduced, the efficiency will be low. In this case, the athlete will have to do exercises that include aspects such as squats with balanced loads or squats with side scales.

Functional stability of the lower limb joints remains an essential condition in ensuring physical training that corresponds to the requirements of elite skiing.

Research question

Does knowledge of skiers' physical fitness parameters help coaches develop training plans that include injury prevention elements?

Research purpose

The research aims to identify the most effective methods and means leading to the development of joint mobility and the prevention of injuries in non-specific training and implement them in the training programmes of the national team to help skiers achieve the best performance.

Methodology

Participants

This research is a case study involving only one male athlete (B.M.) who was informed about testing requirements and agreed on how the experiment was conducted. The research was carried out in the gym of the Carpați Sinaia Sports Club as follows:

- On 5 June 2020, the initial test took place by applying the Y Balance Test.
- Between 6 June 6 2020 and 28 August 2020, non-specific training programmes were applied, which included methods of developing lower limb mobility and means of strengthening the knee joint.
- On 29 August 2020, the final test took place.

Research methods used

The research methods used in this study were:

- Scientific documentation - provided the theoretical substantiation of the paper and involved searching for the latest topic-related sources of information (books, journals, school curricula, iconographic and computerised materials) in databases such as Google Scholar, EBSCO, Scopus, Web of Science, ProQuest and SpringerLink.
- Pedagogical observation - consisted in systematically monitoring the motor actions and activities performed by the research participant.
- Testing method - aimed at obtaining as accurate information as possible on lower limb mobility by using the Y Balance Test (Figure 1).
  The calculation formula was: [(A + PM + PL)/ Leg length × 3] x 100, where A - previously, PM - posteromedial, PL - posterolateral.
  Absolute reach distance (cm) = (Reach 1 + Reach 2 + Reach 3)/3
  Composite reach distance (%) = Sum of the 3 reach directions/ 3 times the limb length *100

Figure 1. Y Balance Test (Walker, 2016)

- Mathematical statistics - the relationships between variables, the prediction and understanding of phenomena subject to statistical analysis were achieved through the progress rate using the formula: (FT-IT/FT) x 100 (Tüdos, 1993).
- Graphical method - allowed the visualisation and presentation of figures, data and calculated indicators, offering suggestions for interpretation especially in comparative terms.

Experimental design

The assessment was done using the Y Balance Test at the beginning and end of the experiment. Through this test, we aimed to achieve a standardised situation with a task to be performed. The assessment consisted in the statistical comparison of the results obtained by the athlete in the initial and final tests.

The Y Balance Test was used to determine the functional symmetry of the lower limbs by measuring leg extension in three directions (anterior, posteromedial, posterolateral). The length of each lower limb was also measured.

To perform the test, the athlete must warm up as well as possible. The warm-up must correspond to the biomechanical and physiological nature of the test. In addition, sufficient recovery (e.g., 3-5 minutes) should be provided after warm-up and before starting the test. The test was performed three times (therefore, in all three planes) and the best result was recorded. The athlete is required to stand on a centre platform and slide a reach indicator along a static frame while maintaining balance. The test assesses the dynamic limits of stability in the single-leg position while the opposite leg reaches in the three aforementioned directions and marks the distance to reach the tip of the foot. During testing, the moving foot was not allowed to touch the floor.

In accordance with the purpose of the paper, we designed a programme for the development of lower limb mobility during the basic preparatory period. Anatomical adaptation training was performed for eight weeks in order to prepare the athlete's muscles for future demands, and ligaments, tendons and joints to cope with the subsequent phases of prolonged and strenuous exercise. The programme continued with elongation methods that alternated with classical (passive) stretching. The muscles and joints involved were isometrically tenses for 8-10 seconds, then relaxed for a short time and immediately stretched for 12-14 seconds. These sequences were repeated 2 to 6 times per muscle group or joint.

Results

The Y Balance Test was used to determine the functional symmetry of the lower limbs by measuring leg extension in three directions (anterior, posteromedial, posterolateral) (Figure 2).

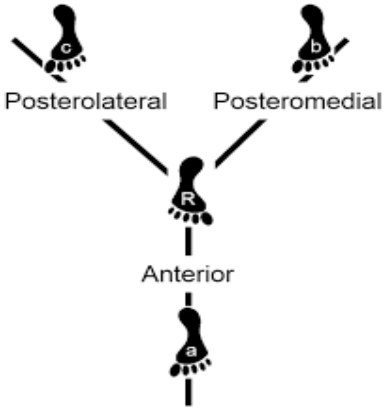

Figure 2. Directions for assessing the functional symmetry of the lower limbs

The results obtained by the athlete in the initial and final tests are shown in Tables 1-4.

Table 1. *Results obtained in the initial Y Balance Test (left foot vs. right foot)*

Initial test	Left foot	Right foot
Anterior (cm)	54	56
Posteromedial (cm)	100	105
Posterolateral (cm)	100	105
Absolute reach distance (cm)	84.66	88.66
Composite reach distance (%)	85.5	89.5

Table 2. *Results obtained in the final Y Balance Test (left foot vs. right foot)*

Final test	Left foot	Right foot
Anterior (cm)	61	61
Posteromedial (cm)	112	113
Posterolateral (cm)	112	112
Absolute reach distance (cm)	95	95.33
Composite reach distance (%)	95.9	96.9

Table 3. *Statistical data for Y Balance Test – Left foot*

Y Balance Test	Left foot			
	Initial test	Final test	Difference between tests	Progress rate
Anterior (cm)	54	61	7	11.47
Posteromedial (cm)	100	112	12	10.71
Posterolateral (cm)	100	112	12	10.71
Absolute reach distance (cm)	84.66	95	10.34	10.88
Composite reach distance (%)	85.5	95.9	10.4	10.52

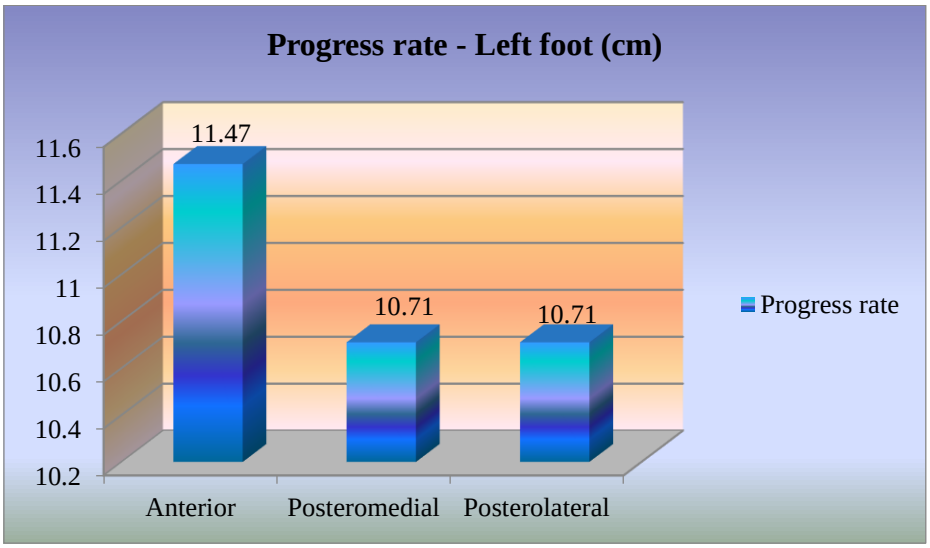

Figure 3. Progress rate – Left foot

According to the data obtained from the tests (Table 3, Figure 3), the investigated athlete recorded an improvement in dynamic balance, which was determined by the increased

distance travelled with the left leg in the three planes, the difference between tests being 7 cm (anterior plane) and 12 cm (posteromedial and posterolateral planes). The progress rate obtained after performing the motor programme to improve balance was 11.47% in the anterior plane and 10.71% in the posteromedial and posterolateral planes.

Table 4. *Statistical data for Y Balance Test – Right foot*

Y Balance Test	Right foot			
	Initial test	Final test	Difference between tests	Progress rate
Anterior (cm)	56	61	5	8.19
Posteromedial (cm)	105	113	8	7.07
Posterolateral (cm)	105	112	7	6.25
Absolute reach distance (cm)	88.66	95.33	10.56	6.99
Composite reach distance (%)	89.5	96.9	7.4	7.63

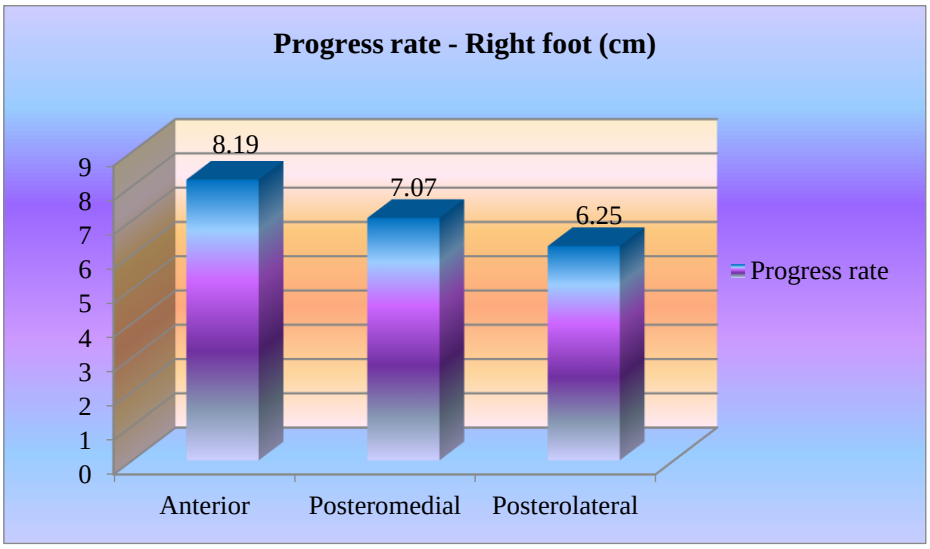

Figure 4. Progress rate – Right foot

The results obtained after the tests (Table 4, Figure 4) certified that the investigated athlete recorded an improvement in dynamic balance, which was determined by the increased distance travelled with the right foot in the three planes, the difference between tests being 5 cm (anterior plane), 8 cm (posteromedial plane) and 7 cm (posterolateral plane). The progress rate obtained after performing the motor programme to improve balance was 8.19% in the anterior plane, 7.07% in the posteromedial plane and 6.25% in the posterolateral plane.

The athlete has improved his ability to perform leg movements in all three planes while maintaining a stable and balanced position, which are vital elements in preparing a skier.

Conclusion

The research results have clearly and concretely highlighted the role and importance of training the flexibility of muscles and joints and implementing it in the training programmes for elite athletes.

The proposed training programmes, which were accepted by the athlete, proved to be viable and effective, which was supported by the data obtained from the tests performed.

The results obtained have definitely shown that athletic training must be done with strictly specialised means that mainly develop the qualities required by the specifics of alpine skiing, the muscle groups involved in the effort and the type of effort. Elite sports training aims to continuously increase exercise capacity in order to develop the level of enduring a large volume of work per training lesson and maintain the intensity for as long as possible. The study demonstrates the clear progress of the tested athlete due to the independent variable of our research.

Because the research is a case study involving only one participant, we believe that the results obtained can open new directions for the application of training programmes to the national team skiers.

During the training of elite athletes, the coach will try to mobilise all individual performance resources by differentiating the training process according to the characteristics of each athlete. Good differentiation in the training process based on individual aspects depends on the coach's talent, knowledge, analytical ability and art of making the athlete achieve maximum performance.

We hope that the findings of this study will translate into better results in competitions but also a decrease in the risk of injury for athletes.

Authors' Contribution

All authors have equally contributed to this article.

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