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PROPRIOCEPTION TESTING IN JUNIOR ATHLETES TRAINING USING THE *GYKO* SENSOR

S. ALECU[1] D. IONESCU-BONDOC[1]

Abstract: *Proprioceptive training is crucial for enhancing coordination, balance, and injury prevention in athletes, especially in their developmental stages. This study investigates the application of the Gyko sensor for testing proprioceptive abilities in junior athletes. The Gyko sensor, a portable motion analysis device, provides real-time data on movement and postural control. The study assesses the effectiveness of proprioceptive training by analyzing parameters such as balance, stability, and joint positioning accuracy in young athletes. Results highlight the sensor's potential in monitoring improvements and tailoring individualized training programs to optimize athletic performance and reduce injury risk.*

Key words: *sensor technology, Gyko Sensor, proprioceptive training, junior athletes, proprioception.*

1. Introduction

Proprioception, often referred to as the „sixth sense", is the body's ability to sense its position and movement in space. This neuromuscular function is critical for maintaining balance, coordination, and executing complex motor tasks efficiently.[3]

In the context of sports, proprioception plays a pivotal role in preventing injuries and enhancing athletic performance, particularly in young, developing athletes. Junior athletes, who are in the process of refining their motor skills and building a foundation for long-term athletic success, benefit significantly from targeted proprioceptive training. Such training not only improves balance and coordination but also fosters the development of fine motor skills that are essential for advanced athletic performance.

Recent advancements in technology have made it possible to assess and monitor proprioception with greater precision.

The implementation of information technology in the sports field is increasingly complex, aiming at both monitoring the training process and

[1] PhD., *Transilvania* University of Braşov.

evaluating the motor and functional parameters of athletes [2].

The Gyko sensor, a portable motion analysis device, has emerged as a tool that can accurately measure the biomechanical parameters associated with proprioceptive control [1]. This sensor, through its capacity to capture data related to body movement, balance, and stability, presents an opportunity to objectively quantify proprioceptive abilities in athletes. By doing so, it provides valuable insights into the effectiveness of training regimens and helps tailor interventions to meet the specific needs of individual athletes.

Gyko has good inter- and intrarater reliability and excellent concurrent validity compared to the optical motion system for lumbar range of motion. Gyko may be considered as objective measure to measure range of motion for clinical purposes, however trials with patients are currently lacking [8].

Proprioception is a fundamental aspect of an athlete's motor control and performance. It allows individuals to detect changes in joint position, force, and muscle tension, enabling them to respond rapidly to external stimuli [9]. For junior athletes, who are still developing neuromuscular connections and coordination, proprioceptive training is crucial. This training typically involves exercises that challenge the body's ability to maintain stability and control during dynamic movements, such as balancing on unstable surfaces or performing agility drills.

Improved proprioception contributes to better motor learning, which is essential for skill acquisition in sports. It also reduces the likelihood of injury, particularly in high-risk sports where sudden changes in direction or impact are common, such as soccer, basketball, or gymnastics. The younger the athlete, the more critical it is to enhance proprioceptive awareness, as their bodies are more adaptable during these formative years.[7]

However, assessing proprioception can be challenging. Traditional methods often rely on subjective assessments or basic balance tests, which do not provide a comprehensive understanding of an athlete's neuromuscular control. This is where technology, such as the Gyko sensor, offers a significant advantage.

In recent years, the integration of technology in sports science has revolutionized the way athletes train and monitor their progress. Devices that measure movement, force, and muscle activation have provided coaches and trainers with a deeper understanding of athletic performance. The Gyko sensor, in particular, has proven to be a valuable tool for measuring proprioception because it is portable, user-friendly, and capable of capturing a wide range of biomechanical data.

The challenges of modernizing and adapting physical and sports education are complex and involve changes in the specific objectives, forms of organization and technologies and methods used and aim at both the training of teachers and the work of student [4].

The Gyko sensor works by using accelerometers and gyroscopes to measure motion in multiple planes. It can track changes in body position, velocity, and acceleration, providing real-time feedback on how well an athlete is controlling their movements. This data is invaluable for identifying areas where proprioceptive control may be lacking, allowing for targeted interventions [13].

In junior athletes, whose proprioceptive abilities are still developing, the Gyko sensor can be used to monitor progress over time. By regularly testing athletes, coaches can determine whether proprioceptive training is yielding the desired improvements in balance, stability, and movement efficiency. This allows for the adjustment of training programs to better suit the needs of the individual athlete, thereby optimizing their development [12].

The importance of proprioceptive training for junior athletes cannot be overstated. During adolescence, athletes undergo significant physical changes that affect their balance, coordination, and overall athletic ability. Proprioceptive training helps to enhance the neuromuscular control needed to adapt to these changes and maintain high levels of performance.

Common proprioceptive training exercises include balance drills on unstable surfaces, such as balance boards or foam pads, and dynamic movements that challenge stability, such as lateral jumps or agility drills. These exercises help to improve the body's ability to react to changes in position and maintain control, even during complex or unpredictable movements. The coordination of movements involves a great deal of perception, anticipation, and concentration [6].

For junior athletes, incorporating proprioceptive training into their overall training regimen is essential for injury prevention. Sports-related injuries, particularly to the ankle and knee joints, are often the result of poor proprioceptive control. By improving proprioception, athletes are better able to stabilize these joints during movement, reducing the risk of injury.

In addition to injury prevention, proprioceptive training also contributes to performance enhancement. Athletes with superior proprioceptive abilities are able to execute complex movements with greater precision and efficiency. This can lead to improvements in speed, agility, and overall athletic performance.

Injuries associated with falls during exercise were suggested by Yamamoto et al. (2010) to happen more likely in obese students. Pomerantz, Timm and Gittelman (2010) have shown that obese youth are at risk for lower extremity injuries than upper body injuries [14].

The Gyko sensor offers a unique opportunity to objectively assess proprioceptive abilities in junior athletes. Unlike traditional balance tests, which rely on subjective observations or limited measurements, the Gyko sensor provides a comprehensive analysis of an athlete's movement patterns [9]. By capturing data on body position, acceleration, and velocity, the sensor can detect even subtle deficiencies in proprioceptive control.

For example, during a balance test, the Gyko sensor can measure how much an athlete sways while standing on one leg. If the athlete is unable to maintain a stable position, this indicates a lack of proprioceptive control. Similarly, during dynamic movements, the sensor can track how well the athlete maintains balance and control, providing insights into their ability to perform complex motor tasks.

This data can then be used to guide training interventions. If the sensor detects deficiencies in proprioceptive control, the athlete can be prescribed specific exercises to address these issues.

Over time, as the athlete continues to train, the Gyko sensor can be used to monitor progress and ensure that the training is effective.

2. Materials and Methods

For this study we used GYKO inertial sensor, which consists in a single IMU (dimensions: 50x70x20 mm, mass: 35g) that contains three dimensional accelerometer, gyroscope and magnetometer with an aquisition frequency of 1000 Hz [16].

Proprioception refers to the conscious and unconscious perception of postural balance, muscle sense, and joint stability. Proprioceptive training has the potential of improving sports improves technique because of the information it provides about the situation of the body as a whole [15].

Within the proprioceptive training program, we designed 4 exercises to improve static balance.

The proprioceptive training program included the following exercises:

Exercise no.1:

From standing on the forward leg semi-flexed and full sole on the Bosu ball, and with the trailing leg with the knee bent on the fitness ball.

Energetic arm movements are performed back and forth, while maintaining balance.

Exercise no. 2:

From standing in forward semi-squat, one leg back on the fitness ball and the other forward on the Bosu ball, lift the opposite leg with a forward calf push – up

Exercise no. 3:

From sitting with legs flexed at 90 degrees on the inverted Bosu balance ball, leaning against the wall with your back on the fitness ball, raising one leg semi-flexed forward.

Exercise no. 4:

Lying prone, support on the toes on the fitness ball and on the hands on the balance ball Bosu inverted, flexing the thigh on the pelvis with the leg forward - sideways.

These exercises were monitored using the Gyko inertial sensor, which recorded a series of parameters, for 5 seconds / test, of which we considered relevant for the most accurate interpretation of the results, the following:

Length [D_L] (Length) – Represents the total length of the trajectory obtained as the sum of the distances from one point to the next. It is measured in cm.

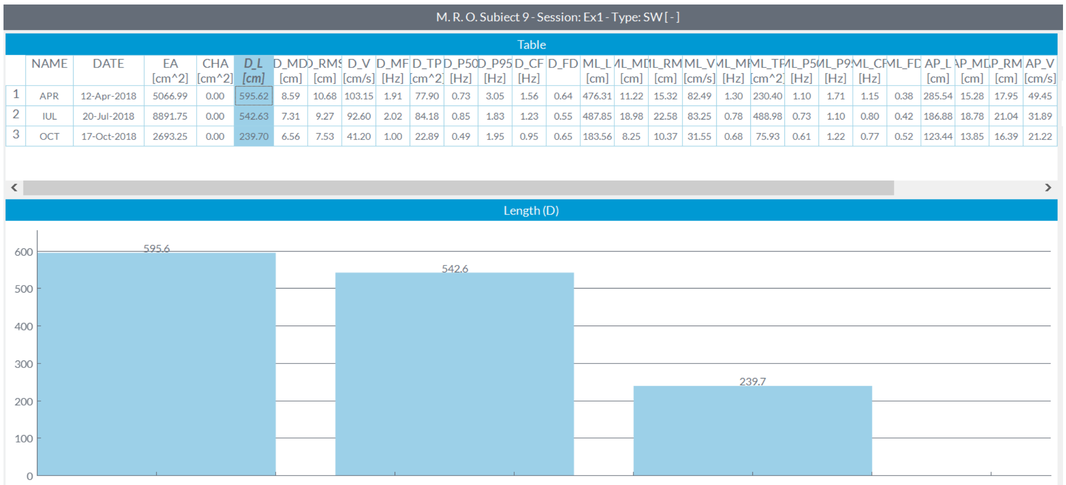
Mean Distance [D_MD] (Mean Distance) – Represents the average distance from the midpoint of the trajectory. It is measured in cm.

Speed [D_V] (Velocity) - This is the average speed of the trajectory. It is measured in cm/s.

The *Gyko* inertial sensor, placed on the subject's chest, follows a 2D plane trajectory vertically and horizontally, plotting on the graph the trajectory followed by the subject during the execution and represented graphically in the figures below.

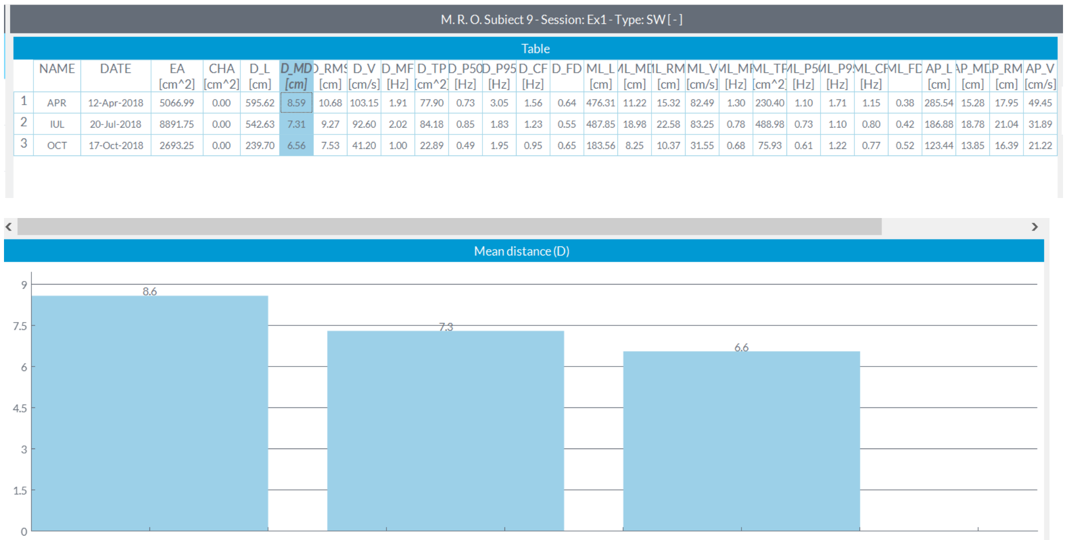
The longer the path length, the more unstable the balance can be said to be because the subject's body experiences wider and less controlled oscillations.

The larger the average distance, the greater the horizontal swing and the greater the deviation from the vertical midline, suggesting that the subject's stability is lower.



	NAME	DATE	EA [cm^2]	CHA [cm^2]	D_L [cm]	D_MD [cm]	D_RMS [cm]	D_V [cm/s]	D_MF [Hz]	D_TP [cm^2]	D_P50 [Hz]	D_P95 [Hz]	D_CF [Hz]	D_FD	ML_L [cm]	ML_MD [cm]	ML_RM [cm]	ML_V [cm/s]	ML_MF [Hz]	ML_TP [cm^2]	ML_P50 [Hz]	ML_P95 [Hz]	ML_CF [Hz]	ML_FD	AP_L [cm]	AP_MD [cm]	AP_RM [cm]	AP_V [cm/s]
1	APR	12-Apr-2018	5066.99	0.00	595.62	8.59	10.68	103.15	1.91	77.90	0.73	3.05	1.56	0.64	476.31	11.22	15.32	82.49	1.30	230.40	1.10	1.71	1.15	0.38	285.54	15.28	17.95	49.45
2	IUL	20-Jul-2018	8891.75	0.00	542.63	7.31	9.27	92.60	2.02	84.18	0.85	1.83	1.23	0.55	487.85	18.98	22.58	83.25	0.78	488.98	0.73	1.10	0.80	0.42	186.88	18.78	21.04	31.89
3	OCT	17-Oct-2018	2693.25	0.00	239.70	6.56	7.53	41.20	1.00	22.89	0.49	1.95	0.95	0.65	183.56	8.25	10.37	31.55	0.68	75.93	0.61	1.22	0.77	0.52	123.44	13.85	16.39	21.22

Fig. 1. *Path length for exercise no. 1, subject M.R.O.*



	NAME	DATE	EA [cm^2]	CHA [cm^2]	D_L [cm]	D_MD [cm]	D_RMS [cm]	D_V [cm/s]	D_MF [Hz]	D_TP [cm^2]	D_P50 [Hz]	D_P95 [Hz]	D_CF [Hz]	D_FD	ML_L [cm]	ML_MD [cm]	ML_RM [cm]	ML_V [cm/s]	ML_MF [Hz]	ML_TP [cm^2]	ML_P50 [Hz]	ML_P95 [Hz]	ML_CF [Hz]	ML_FD	AP_L [cm]	AP_MD [cm]	AP_RM [cm]	AP_V [cm/s]
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2	IUL	20-Jul-2018	8891.75	0.00	542.63	7.31	9.27	92.60	2.02	84.18	0.85	1.83	1.23	0.55	487.85	18.98	22.58	83.25	0.78	488.98	0.73	1.10	0.80	0.42	186.88	18.78	21.04	31.89
3	OCT	17-Oct-2018	2693.25	0.00	239.70	6.56	7.53	41.20	1.00	22.89	0.49	1.95	0.95	0.65	183.56	8.25	10.37	31.55	0.68	75.93	0.61	1.22	0.77	0.52	123.44	13.85	16.39	21.22

Fig. 2. *Average trajectory distance for exercise no. 1, subject M.R.O.*

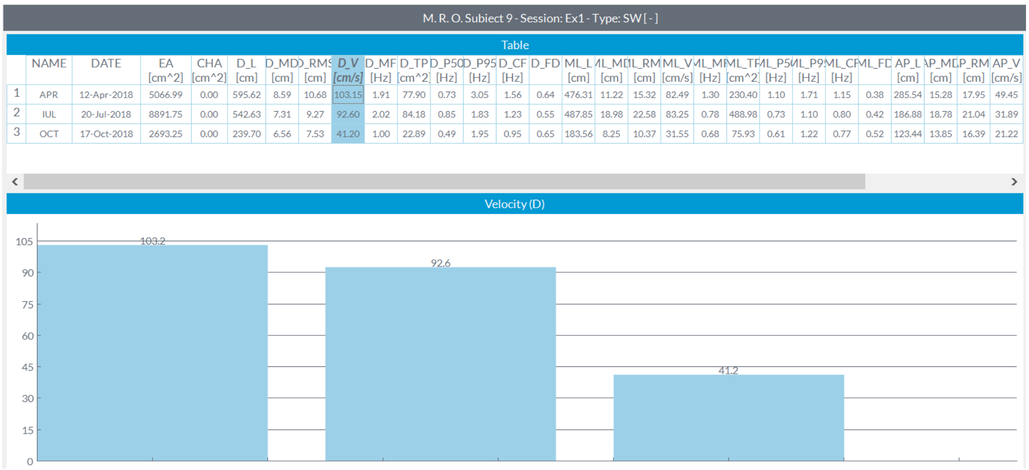

Fig. 3. *Trajectory travel speed for exercise no. 1, subject M.R.O.*

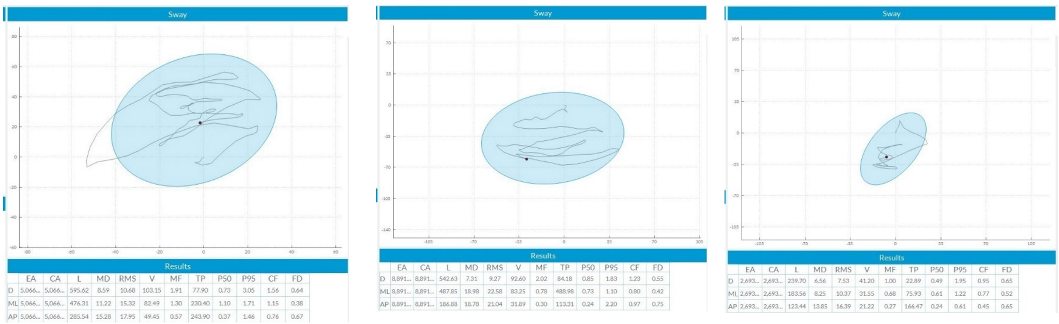

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Fig. 4. *Graphic representation of the trajectory for exercise no. 1, subject M.R.O., initial, intermediate and final testing*

The higher the speed of the trajectory, the higher the frequency of the oscillatory movements and the higher their number, the balance of the subject being directly proportional to them.

The testing monitoring took place 3 times, the initial one in April, the intermediate one in July and the final one in October 2023.

In this study, we analyzed the data of 3 parameters measured by the Gyko inertial sensor placed on the chest of the 5 subjects, who performed one of the 4 repetitions of the proprioceptive training program.

3. Results

In the figures presented we can see the graphic representation of the parameters of the subject no. 1, recorded following the monitoring test of the 3 testing sessions of the individualized proprioceptive training program for the exercise no. 1.

From the following statistics we can note that in the case of the measurements of the exercises included in the monitoring tests following the proprioceptive training program, the values constantly improve as the subjects advance and perfect their proprioceptive motor skills, active balance and coordination skills are increasing considerably in the 9th month of the program.

After the charts and the graphic representations, we can see the results of all the 5 subjects included in the study.

Exercise no. 1 – 3 tests, 5 subjects values recorded Table 1

Test	Parameter	Subject no. 1	Subject no. 2	Subject no. 3	Subject no. 4	Subject no. 5
Initial Test	D_L (cm)	595.62	632.25	585.21	414.55	442.13
	D_MD (cm)	8.59	9.66	8.68	8.93	7.57
	D_V (cm/s)	103.15	115.42	124.25	105.14	93.88
Intermediate Test	D_L (cm)	542.63	610.18	414.58	405.42	470.77
	D_MD (cm)	7.31	9.51	7.54	7.77	6.65
	D_V (cm/s)	92.60	100.69	88.79	99.96	92.84
Final Test	D_L (cm)	239.70	550.32	365.25	345.22	398.78
	D_MD (cm)	6.56	7.44	5.12	6.65	6.24
	D_V (cm/s)	41.20	91.23	59.66	97.58	69.63

In figures above we can see the graphic and tabular representation of the parameters of the subject recorded following the monitoring tests of the 3 testing sessions of the individualized proprioceptive training program for the exercise no. 1.

From the above statistics we can note that in the case of the measurements of both exercises included in the monitoring tests following the individualized proprioceptive training program, the values constantly improve as the subject advance and perfect their proprioceptive motor skills, impulse contact times decreasing and impulse power increasing considerably in the 9th month of the program.

4. Interpretation

Improvement in proprioception: The decrease in both displacement and velocity from the Initial to Intermediate tests suggests that the proprioceptive training was effective in improving the athletes' control and stability.

Final Test Variations: The increase in displacement in the Final test could indicate a different training focus or a temporary regression. However, the continued decrease in velocity suggests that the athletes maintained or further improved their control and stability.

4.1. Initial test results

The *Initial test* serves as the baseline measurement for the athletes. The displacement values range from 59.56 to 95.62 cm, and the velocity values range from 93.88 to 124.25 cm/s. These values indicate the initial proprioceptive control and stability of the athletes before any training intervention.

4.2. Intermediate test results

In the *Intermediate test*, both displacement and velocity values show a significant decrease across all subjects. Displacement values range from 40.77 to 63.10 cm, and velocity values range from 78.79 to 100.59 cm/s. This reduction suggests that the proprioceptive training was effective in improving the athletes' control and stability. Lower displacement and velocity values indicate better proprioceptive control, as the athletes are able to maintain more stable and controlled movements.

4.3. Final test results

The *Final test* results present a mixed picture. Displacement values increase for all subjects except Subject 1, ranging from 239.70 to 550.32 cm. However, velocity values continue to decrease, ranging from 41.20 to 91.23 cm/s. The increase in displacement could suggest a different phase of training where higher displacement is expected, or it could indicate a temporary regression.

The continued decrease in velocity, however, suggests that the athletes maintained or further improved their control and stability.

Results and comparison Table 2

Test	D_L (cm)	SD (D_L)	D_MD (cm)	SD (D_MD)	D_V (cm/s)	SD (D_V)
Initial Test	533.95	88.07	8.69	0.67	108.37	10.48
Intermediate Test	488.72	78.00	7.76	0.95	94.98	4.60
Final Test	379.85	100.47	6.40	0.75	71.86	20.64

Comparison	% Change D_L	% Change D_MD	% Change D_V
Initial to Final Test	-27.37%	-26.15%	-33.20%
Intermediate to Final Test	-21.54%	-16.94%	-25.02%

Statistical Analysis using Paired t-test

To determine the statistical significance of the changes observed, we performed a paired t-test comparing the Initial and Intermediate test results for displacement (D). The calculated t-value was 6.82, which is greater than the critical t-value of 2.776 for 4 degrees of freedom at a 0.05 significance level. This indicates that the difference between the Initial and

Intermediate displacement is statistically significant.

Interpretation of Paired t-test Results

The significant decrease in displacement from the Initial to Intermediate test suggests that the proprioceptive training had a positive impact on the athletes' proprioceptive abilities. The athletes were able to achieve better control and stability, as evidenced by the lower displacement values. The continued decrease in velocity from the Initial to Intermediate test further supports this conclusion, indicating improved stability and control.

4. Conclusions

There was a consistent reduction in all parameters across the tests, with the most significant drop seen in D_V (cm/s) (velocity) from the initial to the final test. The data indicates a measurable change in proprioception and performance over time, which could reflect the effects of the training regimen.

The data indicates that proprioceptive training using the Gyko sensor has positively impacted the junior athletes' proprioceptive abilities, as evidenced by the improvements in displacement and velocity. The variations in the Final test warrant further investigation to understand the underlying causes.

The data from the study indicates that proprioceptive training using the Gyko sensor has a positive impact on junior athletes' proprioceptive abilities. The significant improvements observed in both displacement and velocity from the Initial to Intermediate tests suggest that the training was effective in enhancing the athletes' control and stability. The variations observed in the Final test warrant further investigation to understand the underlying causes, but the overall trend indicates continued improvement in proprioceptive control.

This interpretation highlights the importance of proprioceptive training in improving athletic performance and provides valuable insights into the effectiveness of such training programs.

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