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Low-Cost Device For Vertical Jump Measurement In Sports Training

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Abstract:
Background: *The registration and estimation of vertical jumps allow for the evaluation of athletic performance. From this data, variables such as strength, speed, power, work, and calorie expenditure can be determined. Consequently, it becomes crucial to have tools that enable precise measurements of this movement. In this regard, accelerometry offers certain advantages to fulfill this need. Therefore, the objective of this academic work was to program and validate a low-cost device based on accelerometry (AD), aimed at calculating various parameters related to vertical jumps.*
Materials and Methods: *The study utilized a BNO055 sensor and a Raspberry Pi Zero W 2, with the programming language Python, version 3.9. Validation was conducted using the PROJUMP mat and the My Jump2 app. The evaluation jumps (Squat Jumps) were simultaneously executed with all three devices by subjects of both sexes (n=26), aged between 24±5 and 25±6 years. Data analysis involved one-way ANOVA, post hoc Tukey's multiple comparison test, and linear correlation.*
Results: *The results of this research provide valuable insights into the performance and characteristics of vertical jumps, demonstrating the effectiveness of the low-cost accelerometer-based device for assessing various parameters related to athletic performance. These findings have implications for training, talent identification, and performance monitoring in sports and physical activities. Accelerometer-based device (AD) demonstrated high correlation and agreement with standard references such as the My Jump2 mobile application and the PROJUMP jump mat for measuring key parameters, including height, flight time, velocity and power during vertical jumps (Squad jump).*
Conclusion: *These findings support the validity and accuracy of AD device, suggesting that it can serve as a reliable alternative for assessing jump performance in sports training.*
Key Word: *Accelerometry. Squad Jump. Physical Activity Measurement.*

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I. Introduction

An athlete's performance profile should encompass physiological aspects, biomechanical and anthropometric measurements, and performance-related parameters relevant to the athlete's discipline. The measures that constitute an athlete's profile in a sport may include aerobic capacity, anaerobic/lactate threshold, sprint repetition capacity, maximum sprinting ability (acceleration and top speed), agility, maximal strength, upper and lower body ballistic strength, speed and power production, muscle architecture, anthropometry, functional movement, and flexibility[1]. In this context, vertical jumps are fundamental to complement performance in many sports, both team and individual[2]. They can also be used to evaluate and compare athletes' performance at different levels, as the height reached during the execution of the jump provides the opportunity to determine variables such as strength, speed, power, work, calorie expenditure, among others[3]. Indeed, the need for tools that enable precise measurements of vertical jumps is crucial, and accelerometry stands out as one of the technologies that has garnered significant interest among coaches and researchers. The appeal of accelerometry lies in its capability to measure multiple variables with high precision and in real-time, making it particularly valuable in the field of sports training[4]. There are several types of vertical jumps, with the most applicable ones in sports and physical education being those described by Carmelo Bosco.

These jumps consist of six types of vertical jumps: Squat Jump (SJ), Countermovement Jump (CMJ), Squat Jump with additional load, Abalakov Jump, Drop Jump, and 15-Second Jump. All of them have the objective of reaching the highest possible height during execution[5].

In this context, the objective of this study is the programming and validation of a low-cost device based on accelerometry (AD) to measure different parameters related to vertical jumps. Specifically, the following parameters were determined: force (f), velocity (v), power (p), time (t), and height (h), based on the calculation of the maximum acceleration reached during the execution of the vertical jump.

II. Material And Methods

To compare the prototype, the PROJUMP jump mat and the mobile application My Jump 2 were used. The data collection technique employed was structured observation, aimed at objectively observing the results obtained by each device for each participant. A systematic record of the observations was maintained to facilitate the analysis of the gathered information. The type of jump used for the evaluation was the Squat Jump (SJ), where the participant performed a jump with hands on the hips, maintaining an arm-jarra position, starting from a static knee flexion of 90° [6]. The aim was to eliminate any countermovement and the effects of the stretch-shortening cycle of muscles, followed by pushing the ground to achieve the maximum possible height[7].

Accelerometry-Based Device (AD)

The device consists of a Raspberry Pi Zero W2 board (https://www.raspberrypi.com/products/raspberry-pi-zero-2-w/), an inertial measurement unit BNO055 sensor (https://www.bosch-sensortec.com/products/smart-sensors/bno055/), and an external power bank for energy supply. The sensor was placed on the side of the waist. The device automatically adjusted to a zero value prior to the jump (initial position) and then determined the maximum acceleration and time during the ascending phase of the jump.

PROJUMP Jump Mat

The PROJUMP contact mat triggers a precision USB stopwatch upon contact, which allows for determining different types of jumps. The mat uses the open-access software Chronojump-Boscosystem[8].

My Jump 2 Mobile App

For jump recording, the jump must be filmed with the highest resolution possible using a video camera (Samsung Galaxy S9 Plus mobile device was used, at 60 fps). Subsequently, the segment showing the take-off and landing moments of the subject should be selected9.

Experimental Protocol

After a 15-minute neuromuscular warm-up, participants were instructed on the proper execution technique of the SJ jump. Following several practice attempts, a protocol was conducted, consisting of two repetitions separated by a 3-minute recovery interval. During the first repetition, participants were asked to perform a submaximal jump to familiarize themselves with the protocol and identify possible technical errors. In the second repetition, participants were instructed to perform the SJ jump with maximum intensity, with the gesture simultaneously recorded using all three devices.

Participants

The study participants were students pursuing a degree in Physical Education at the Institute of Physical Education (ISEF) of Udelar. A total of 26 participants were included, comprising 13 males (age 25±6, weight 72.8±13, height 1.76±0.11) and 13 females (age 24±5, weight 62.6±14, height 1.61±0.10).

Equations used in AD

$$X = a * \frac{t\hat{}2}{2}$$

$$p = mg * \left(\frac{h}{hpo} + 1\right) \frac{\sqrt{\ } gh}{2}$$

$$f = mg * \left(\frac{h}{hpo} + 1\right)$$

$$WT = mg(hpo + h)$$

$$v = \frac{\sqrt{\ } gh}{2}$$

$$Gc = \frac{WT}{4.184}$$

Where (f) is force; (mg) the product of mass by gravity; (h) height; (hpo) the push-off distance; (v) velocity; (gh) gravity times height; (p) refers to power; (X) distance; (a) refers to maximum achieved acceleration; (t^2) squared ascending flight time; (Wt) work force, and (Gc) caloric expenditure[10].

Statistical analysis

To calculate the number of participants, the G*Power program was used, with a coefficient of determination (r^2) of 0.25, an effect size of 0.5, a significance level (alpha, α) of 0.05, and a power of 0.80[11]. The Shapiro-Wilk test was applied to determine the data distribution, and a one-way analysis of variance (ANOVA) was conducted to assess the dispersion. Subsequently, a Pearson correlation analysis was performed. For data analysis, the Scipy module of Python version 3.9 was utilized.

III. Result

Height, time, velocity, and power variables were recorded using the devices (accelerometry-based device (AD), My Jump2 application, and PROJUMP jump mat). Hereafter, the following abbreviations will be used: H =jump height, T = jump time, V = jump velocity, and P = jump power. To identify the records from each device, the number 1 was assigned to AD, the number 2 to the My Jump2 app, and the number 3 to the PROJUMP jump mat. The Shapiro-Wilk test analysis demonstrated that the data follows a Gaussian distribution (results not shown).

Table no 1: Shows statistical descriptive

Variable	Std. Deviation	Std. Error	95% CI	Median
H1	5.221	1.024	-3.541 - 3.513	22.35
H2	5.381	1.055	-3.513 - 3.541	22.36
H3	5.320	1.043	-3.498 - 3.556	21.98
T1	0.08348	0.01637	-0.04284 - 0.04321	0.4148
T2	0.05329	0.01045	-0.04322 - 0.04282	0.4300
T3	0.05262	0.01032	-0.04341 - 0.04264	0.4200
V1	0.1260	0.02471	-0.1207 - 0.1216	1.047
V2	0.1308	0.02565	-0.1213 - 0.1220	1.050
V3	0.1585	0.05069	-0.1214 - 0.1222	1.055
P1	398.8	78.22	-219.4 - 217.2	1,293
P2	398.8	78.22	-220.4 - 217.8	1,374
P3	396.7	74.35	-220.6 - 218.2	1,219.6

For variable H, it can be observed that the means are similar. The standard deviation varies slightly, suggesting similarity in the data dispersion (Table no 1). As for variable T, it can be seen that the mean of T1 is the lowest, and the standard deviation of T1 is the highest (Table no 1). On the other hand, V1 and V2 have similar means and dispersions (standard deviation). In contrast, V3 has a slightly higher mean than V1 and V2, and it also has a higher standard deviation, suggesting greater data dispersion (Table no 1). Regarding variable P, it can be observed that the means are similar, as well as the standard deviation, suggesting a similar distribution of the data (Table no 1).

Variable Height (H)

The variables H show a correlation coefficient (r) between H1 and H2 of 0.9782, suggesting a strong positive correlation between the variables. Similarly, the coefficient (r) between H1 and H3 is 0.9760, indicating a high correlation. Likewise, the coefficient of determination (r^2) between H1 and H2 is 0.9570. Similarly, the coefficient of determination (r^2) between H1 and H3 is 0.9526 (Fig.1).

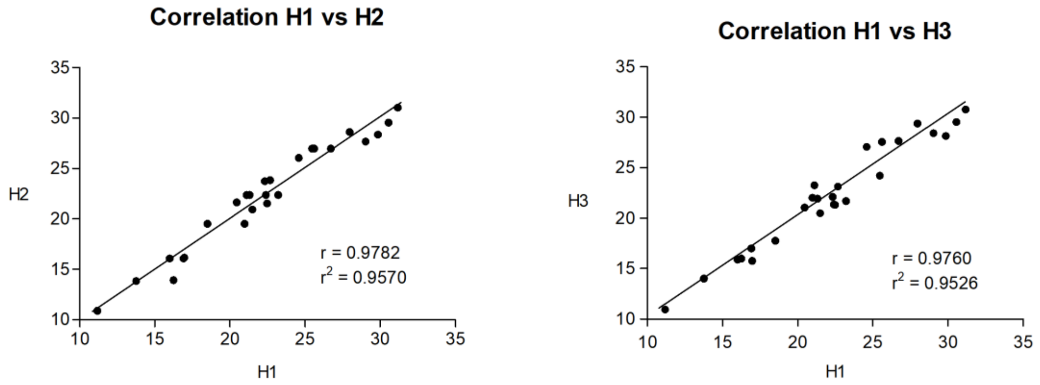


Figure 1: Shows correlation coefficient between H1, H2 and H3.

Variable Time (T)

The variables T show a correlation coefficient (r) between T1 and T2 of -0.2396, suggesting a weak negative correlation between the variables. Similarly, the coefficient (r) between T1 and T3 is -0.2057. On the other hand, the coefficient of determination (r^2) between T1 and T2 is 0.05741. Similarly, the coefficient of determination (r^2) between T1 and T3 is 0.04230 (Fig.2).

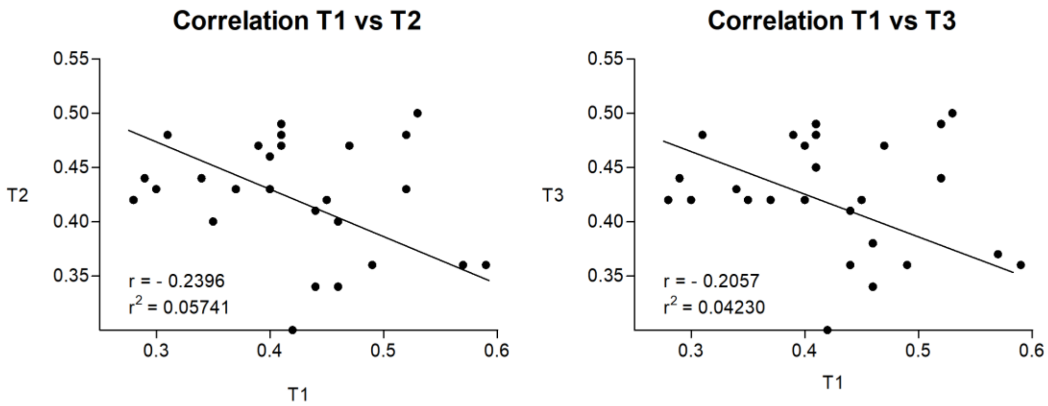
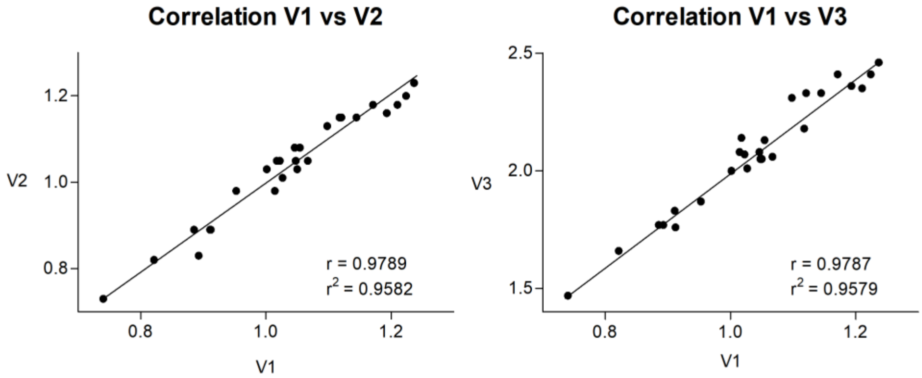


Figure 2: Shows correlation coefficient between T1, T2 and T3.

Variable Velocity (V)

The variable V shows a correlation coefficient (r) between V1 and V2 of 0.9789, and between V1 and V3 of 0.9787, indicating a very strong positive correlation between the variables. The coefficient of determination (r^2) between V1 and V2 is 0.9582, and (r^2) between V1 and V3 is 0.9579 (Fig. 3).

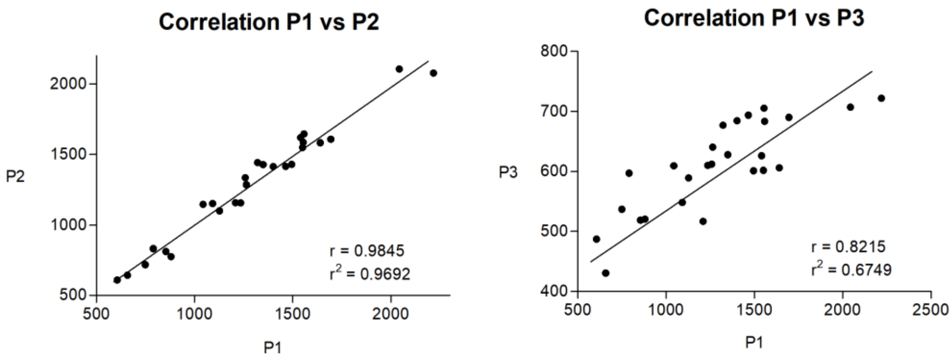
Figure 3: Shows correlation coefficient between V1, V2 and V3.



Variable Power (P)

The variable P shows a high positive correlation between P1 and P2, with a coefficient of (r) of0.9845, and (r) of 0.8215 between P1 and P3. On the other hand, the coefficient of determination (r²) between P1 and P2 is 0.9692, and 0.6749 between P1 and P3 (Fig. 4).

Figure 4: Shows correlation coefficient between P1, P2 and P3.



IV. Discussion

Currently, the use of technological devices to measure various parameters related to physical activity has become increasingly common[12]. However, their evolution and development require specialized training, and access to these devices can be limited due to their high cost. With the aim of promoting the democratization of technology in this field, research has been conducted to develop a wireless and low-cost device capable of measuring height, time, velocity, power, work, and caloric expenditure from vertical jumps using accelerometry. The validation of the device's use and applicability in the scientific domain is a fundamental aspect of the study, with the goal of offering a tool that can be used by a broad spectrum of individuals and facilitate its understanding and teaching in academic and educational settings[13].

The development and validation of a low-cost device for vertical jump measurement in sports training represent a significant advancement in the field of technology applied to physical performance assessment. The economic accessibility and user-friendly nature of this device provide a solution to the cost limitation faced by many coaches and researchers when attempting to access advanced measurement technologies. Accelerometer-based device (AD) demonstrated high correlation and agreement with standard references such as the My Jump2 mobile application[9] and the PROJUMP jump mat8 for measuring key parameters, including height, flight time, velocity and power during vertical jumps (Fig. 1-4). These findings support the validity and accuracy of AD device, suggesting that it can serve as a reliable alternative for assessing jump performance in sports training. The integration of AD device in the scientific and educational domains offers several significant advantages. Firstly, its low cost allows a larger number of coaches and athletes to access advanced performance evaluation technologies, potentially enhancing training quality and understanding athletes' vertical jump capacity. Additionally, its easy implementation in educational and physical education settings provides an opportunity to foster interest and comprehension of the biomechanical and physical principles involved in vertical jumping among students. It is important to mention that factors such as muscle fatigue, previous injuries, joint and muscle flexibility, or ambient temperature were ruled out. This is because the objective of the research was not to achieve maximum performance in the jump but to compare the values collected by the three devices used. By excluding these factors, it is ensured that any difference in the results obtained by the devices is due solely to their performance and not to other external factors.

It is relevant to highlight that during the evaluation, were identified some limitations that may impact the accuracy of the obtained data. The fact that subjects were not familiar with jumping may have influenced the variability of some values, suggesting that familiarization with the jumping technique could be a factor to consider in future research. Furthermore, the manual measurement of the subject's initial distance before the jump may introduce minor errors due to the subject's involuntary movements. Exploring automated measurement methods is recommended to improve accuracy in future implementations.

Another aspect to consider is the lack of comparison of AD device with other accelerometers in the study. While the validation was conducted against widely used references[8,9] including comparisons with other jump measurement devices could further enrich the results and further support the effectiveness of AD device.

V. Conclusion

We have developed and validated a low-cost device for precise vertical jump measurement in the context of sports training. The aim of this research was to design an effective tool that allows reliable and accurate quantification of athletes' and sportspeople's vertical jump capacity during their training program. The device, based on accelerometer technology, offers the ability to measure multiple variables relevant to vertical jump performance, such as the attained height, flight time, velocity, and power generated during the movement. By utilizing a Raspberry Pi Zero W 2 board and a BNO055 inertial sensor, we achieved accurate acceleration data in the relevant axes for jump analysis. The results demonstrated high correlation and agreement between the measurements obtained by our device and those obtained by these standard benchmarks, supporting the reliability and utility of our approach. AD tool represents an accessible and cost-effective option for coaches and researchers interested in quantifying and evaluating vertical jump performance in various sports disciplines. The ability to obtain precise and real-time measurements will optimize training planning and monitoring, talent identification, and early detection of potential technical deficiencies. It is necessary to recognize that a limitation of the study has been not comparing the results obtained by the three devices with another accelerometer. This is an important limitation that could have been addressed to obtain a more complete and accurate comparison of the devices used, especially regarding the prototype.

In conclusion, this low-cost device shows great potential for vertical jump analysis in sports training, providing a practical and reliable solution to enhance athletes' performance and foster their development in the sports realm. We continue to work on improving and expanding this technology, with the goal of further contributing to the advancement of sports science and physical education.

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