8th International Scientific Conference
Technics and Informatics in Education
Faculty of Technical Sciences, Čačak, Serbia, 18-20th September 2020

Session 2: *IT Education and Practice*

Professional paper
UDC: 004.2:621.39

Smartphone Application for Evaluation of Jumping Rope Exercise in Physical Education

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Abstract: *This paper presents the usage of smartphones in the evaluation of student activities in physical education. Results from jumping rope exercises are collected by smartphone sensors and data is processed and can be used by the teacher for precise evaluation. For this purpose, we developed an experiment-based on the Phyphox platform using a built-in accelerometer to measure student performance in jumping rope exercises. This application enables remote evaluation which is convenient for recent virtualization of education due to ongoing pandemic.*

Keywords: *physical education; jumping rope; smartphone; sensor; accelerometer.*

1. INTRODUCTION

The concept of teaching physical education is based on the improvement of student's physical abilities, motor skills and knowledge in the field of physical and health culture. The realization of these goals of teaching physical education is achieved through various and systematic motor activities, which contribute to the integral development of students' personalities. Evaluation of student results on these activities requires some basic technical equipment, such as stopwatch, tape measure.

The closure of schools around the world due pandemic outbreak has forced teachers to conduct online lectures and evaluate student performance remotely. The subject of physical education faced one of the biggest challenges for online evaluation and it relied on students taking video recordings of their exercises which are then evaluated by teachers.

Smartphones include built-in sensors that can be used to directly measure student activity, and increase the accuracy of student evaluation. In this paper, we developed a smartphone application for jumping rope exercise which evaluates student performance base on reading from a built-in accelerometer which is present on every smartphone.

2. JUMPING ROPE EXERCISE

2.1. Evaluation

Evaluation is an integral part of the teaching and learning process, which ensures constant monitoring of the achievement of prescribed outcomes and student achievement standards. The main purpose of assessment is to improve the quality of the learning process [1-3]. Assessment is the process of monitoring and evaluating the flow and outcomes of learning, and assessments are the outcome or product of that process.

The principles of evaluation are:

- Objectivity in evaluation according to established criteria,
- The relevance of the evaluation,
- Use of various evaluation techniques and methods,
- Fairness in evaluation,
- Regularity and timeliness in evaluation,
- Evaluation without discrimination and separation on any basis,
- Respect for individual needs, differences, ages, previous student achievements and current conditions in which evaluation takes place.

Monitoring the development, progress and achievement of student achievement during the school year is done by formative and summative assessment. The formative assessment represents regular monitoring and assessment of progress in achieving the prescribed outcomes, standards of achievement and engagement within the compulsory subject. It must be guiding, developmental, preventive (prevents failure), descriptive. Summative assessment evaluates the achievement of students at the end of the teaching period against certain standards (grade at the end of the year, in the semester, grade in the quarter...). It must be concluding, evaluative, at the end of the learning process.

2.2. Jumping rope working technique

Jumping rope is a sports equipment used by the children from the earliest age. It can be either handmade or be found in almost any sports equipment store at affordable prices. The length of the jumping rope should match the height of the student. The optimal length is determined by the student standing in the middle section of the jumping rope in the connecting position, and pulling the ends which reach exactly to the armpits.

The proper technique of working with the device requires its proper holding. The jumping rope must not be held convulsively, but quite casually so that its ends lie between the thumb and forefinger. The convulsive posture reduces the amplitude of movement in the wrist and thus the mobility of the device. The basis of the technique of working with a jumping rope are:

- Turning the jumping rope in the wrist joint;
- Rotating the jumping rope with shoulder and elbow joint movements.

Turning the jumping rope with movements in the wrist joint is the basic technique for all movements of small amplitudes and high speeds. The rotation of the jumping rope with movements in the shoulder and elbow joint is performed with the aim of extending the jumping rope, which is necessary when moving large amplitudes, and with a low speed of execution.

The jumping rope exercise is performed in the following way: the rope is held by the ends with lowered hands. The jump is performed by bouncing both legs from the squat position and landing on both legs, ending the movement also in the squat. In the jump phase, the legs and the body is stretched. The rotation of the screw is performed by movements in the wrist, with slightly bent elbows. Jumps can be performed with or without intermediate jumps, with the jumping rope turning back and forth. It is necessary to coordinate the movement of students and the movement of the jumping rope. The goal is to develop skills, strengthen the muscles of the lower extremities, and strengthen the abdominal muscles. There are various variants and combinations of skipping the jumping rope - in place, moving, in pairs, with cross rotation, with double pulling.

2.1. Expected outcomes

Assuming that student-teacher communication takes place online, the student will be able to:

- Recognize the link between physical education and health;
- Names the motor skills to be developed;
- Performs exercises for the development and improvement of motor skills;
- Demonstrates proper technique;
- Explain why the characteristics of physical education are important, to actively participate in the teaching process and to independently implement a particular program;
- Considers the negative influences of the modern way of life;
- Enjoys performing movements and movements.

3. ACCELERATION ANALYSIS OF VERTICAL JUMP

Dynamic and kinematic analysis of a vertical jump, sargent jump, broad jump or jump with the rope shows that these jumps are essentially very similar [4, 5]. When parameters such as the center of mass displacement (CM) and linear acceleration of the body are observed, significant coincidences can be observed in vertical jump and jump with the rope. The difference is observed only in the absolute values of the displacement of the center of mass and linear acceleration, which are somewhat more pronounced in the vertical jump.

Figure 1 shows the different phases that a jumper goes through during a vertical jump. In phase A, the jumper stands still and in an upright position. The position of the center of mass in this phase of the jump is taken to be the reference level, ie equal to zero. The jumper is not affected by additional acceleration except for the acceleration of the Earth's gravity directed vertically downwards.

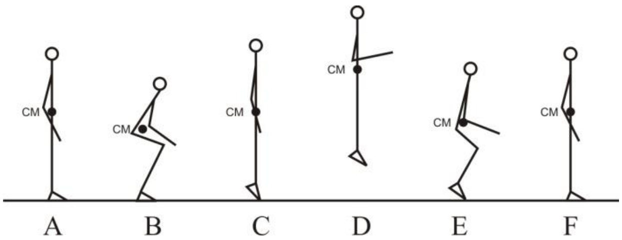

Figure 1. *The different phases that a jumper goes through during a vertical jump*

Phase A is followed by a jump preparation marked by phase B in which the jumper lowers his CM by bending his knees and preparing for the jump. During this phase, the sensor on the phone shows an increase in the value of the linear acceleration (Fig.2). At the end of this phase (preparation for the jump) the maximum value of the CM acceleration, which has a downward direction, is recorded. This results in a linear acceleration directed in the opposite direction since the sensor on the smartphone show the accelerations whose direction is opposite to the direction of the body's movement. Point C indicates the moment when the jumper is reflected and in which the jumper moves upwards, pushing his feet off the ground and straightening his knees. This results in a significant increase in the value of the linear acceleration with the downward direction recorded by the smartphone. At point D, the jumper reaches the maximum height, the linear acceleration on all three axes (X′Y′Z′) is approximately equal to zero, except for the vertical acceleration which is constant and directed vertically downwards throughout the jump (g_o = -9,81 m/s^2). At this point, an acceleration of approximately zero is recorded. It should be noted that in the Phyphox application there is a possibility to record the linear acceleration at all three coordinates of the phone (X’Y’Z’) as well as their sums at absolute values, without taking into account the acceleration of the Earth's gravity (g_o = 0 m/s^2).

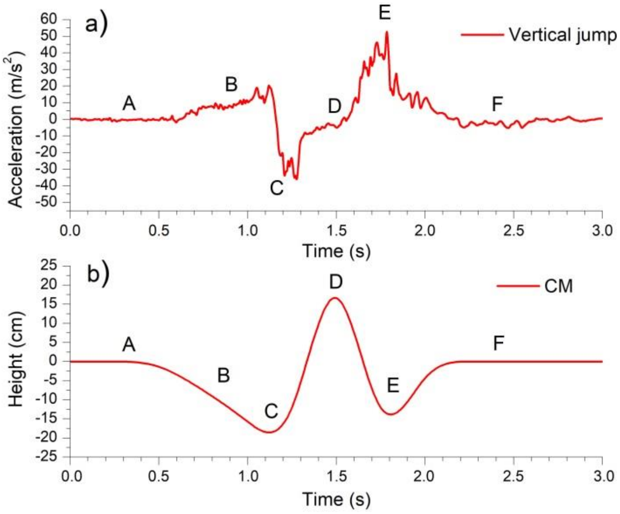

Figure 2. *a) Total linear acceleration registered by the sensor on the smarthpone along all three X’Y’Z ’coordinates during the duration of the vertical jump; b) displacement of the* jumper's CM *during the vertical jump.*

Upon reaching the maximum height, the CM of the jumper begins to descend which increases the value of the linear acceleration registered by the smartphone. At the moment of landing (point E), there is a significant increase in the value of the linear acceleration. Additional peaks that may occur in the phase of reflection (point C) and landing (point E) originate from the movement of the joints and are a consequence of the amortization of the bounce and landing and the movement of the joints during the rotation of the rope. By returning CM to the initial position (point F), the accelerometer records again values that are approximately equal to zero along the X’Y’Z’ coordinates. This phase is identical in characteristics to phase A.

It should be noted that the orientation of the X’Y’Z’ coordinate system that is fixed to the smartphone in relation to the XYZ coordinates that are fixed to the ground does not affect the obtained result. In the Phyphox application, there is an option to summarize the results of linear accelerations on all three axes, with or without the acceleration of the Earth's gravitational field. When jumping, the only condition that the jumper must meet is that his smartphone is in a fixed position during the entire measurement time. Ideally near his center of mass, that is, in the waist area.

4. SMARTPHONE AS SENSOR PLATFORM

Most smartphones have several built-in sensors that measure motion, orientation, and various environmental parameters. These sensors provide high precision raw data that can be used to monitor device movement or positioning in three-dimensional space or to monitor changes in the ambient environment in device proximity.

Phyphox is a free smartphone application that enables the usage of built-in sensors to perform various experiments, primarily in the field of physics. Phyphox application represents an acronym for physical phone experiments and was developed in 2016 at RWTH Aachen University [6]. This application is available on all smartphones running at Android or iOS operating systems. This application allows users to use existing experiments or create programs for new experiments, which can perform some level of data analysis on collected sensor data. Since virtually any student has a smartphone, this can drop the cost of many physics experiments almost to zero.

The application allows usage of different sensors that are present depending on the phone model: accelerometer, gyroscope, magnetometer, light meter, barometer, microphone, proximity sensor and GPS (Fig. 3).

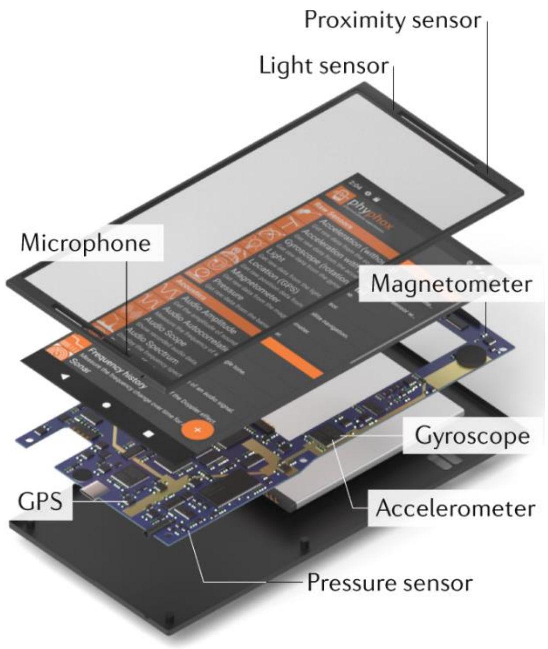

Figure 3. *Typical sensors present in smartphone*

There are lots of predefined Phyphox experiments such as Doppler Effect, sonar, acoustic spectrum, pendulum and spring oscillations, roll and centrifugal acceleration, etc. Processed data can be processed and shared as exported in CSV (Comma Separated Values) or Excel format. The application also allows remote control of the experiment using the built-in web browser interface which can be accessed from the laptop computer or other smartphone via WiFi hotspot.

Besides predefined experiments, users can create custom experiments using Phyphox web Editor [7]. Using the Input tab of this editor, the user can select which sensors will be used in the experiment, and define its properties, such as data rate, range, etc. Then the user creates a layout of experiment screens on the Views tab, in which output data will be presented. These include interactive graphs, buttons, text boxes, labels and numerical output fields. Analysis tab enables users to define algorithms in graphical form using predefined mathematical and program control operations, as well as advanced functions, such as correlation, Fast Fourier transform, smoothing, etc. The experiment is saved in XML form and can be downloaded to smartphones.

5. JUMP ROPE PHYPHOX EXPERIMENT

The accelerometer sensor measures a force applied on a sample mass in three principal axes X, Y, and Z (Fig. 4). The accelerometer will, therefore, experience 9.81 m/s² acceleration caused by Earth's gravitational field while the phone is resting. Earth acceleration will be distributed along different sensor axes depending on the phone orientation.

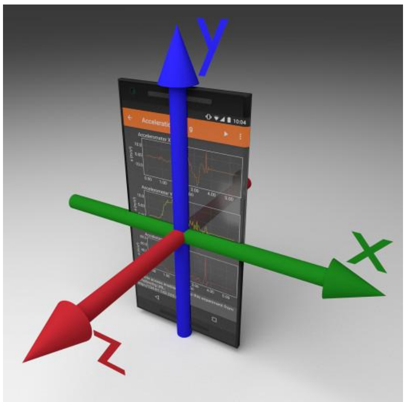

Figure 4. *Accelerometer coordinate system*

Therefore to eliminate the influence of phone orientation on acceleration measurements, absolute acceleration is measured along all three axes (Fig. 5).

$$a = \sqrt{a_x^2 + a_y^2 + a_z^2} \quad (1)$$

The sampling rate for the smartphone accelerometer is model dependant and the typical rate for midrange phone models is around 100 Hz (high-end models achieve sampling rates up to 500 Hz).

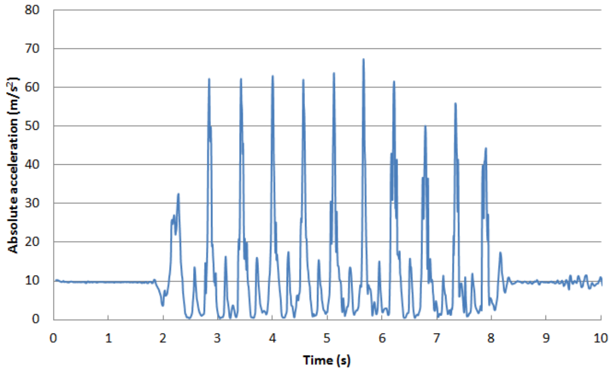

Figure 5. *Raw absolute acceleration from sensor during rope jumping exercise*

Since accelerometer data is susceptible to noise, even when the phone is resting, we calculated RMS (Root Mean Square) value for successive n=10 samples

$$a_{RMS} = \sqrt{\frac{1}{n}\sum_{i=0}^{n} a_i^2} \quad (2)$$

RMS value of absolute acceleration acquired from the accelerometer sensor is calculated in Phyphox Editor as shown in Figure 6.

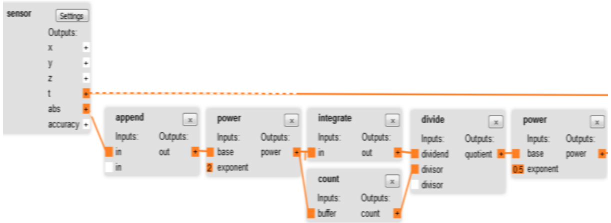

Figure 6. *RMS acceleration calculation*

Calculated RMS values are appended to an array which is shown on the Y-axis of the graph, while the X-axis is acquired from the timer (Fig. 7).

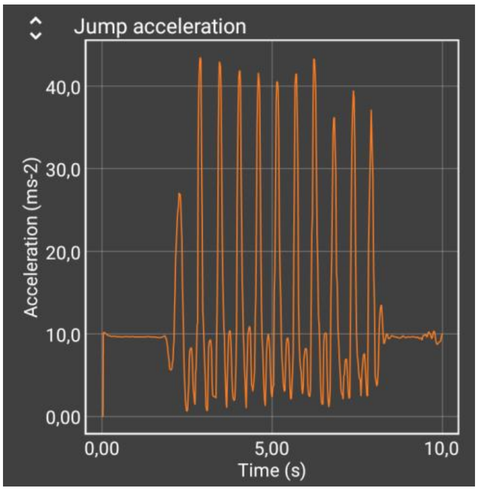

Figure 7. *Graph of RMS acceleration*

Acceleration RMS value is processed by max block which locates the position and values of multiple peaks in the input signal. The threshold field is used to enter threshold value for multiple peaks detection and this value depends on the jumping style, surface type, student's weight, etc. Obtained maximum values are averaged and shown on screen in the form of a jump intensity field. Jumps are then counted using determined positions of detected peaks. Since some jumps can be counted multiple times due to multiple detected peaks, the range filter was used in order to eliminate peaks that are very close to each other (Fig. 8).

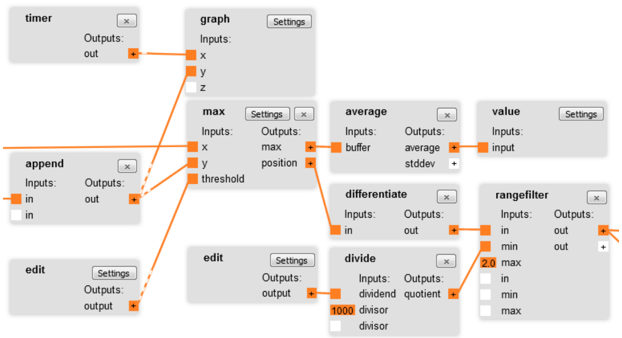

Figure 8. *Locating peaks in RMS acceleration*

Jump duration field is used to enter information about jump duration which is dependant on jumping style (typically 100 ms for turning jump technique and 200ms for rotating jump technique). This value is used to filter all detected peaks which are too close to their neighboring peaks which originate from the same jump. Filtered peaks are counted and displayed on the screen in the form of the jump count field. The average duration between detected peaks is used to calculate jump speed which is also shown on screen.

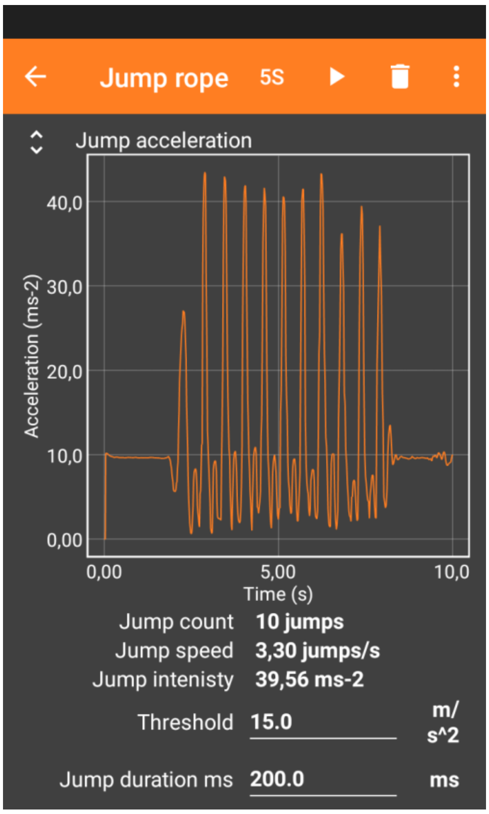

Figure 9. *Layout of Jump Rope experiment*

The screen layout of the realized Phyphox experiment is shown in Figure 9. The experiment can be started with a delay timer which gives students enough time to put his phone in the pocket and start performing the exercise. The student performed 10 jumps, as can be seen on the graph, and all jumps are successfully counted as well as jumps speed of 3.3 jumps per second and jump intensity of 39.56 m/s2. Also, students can share experiment results with teacher and export graph data in form of CSV for further processing on a personal computer.

6. CONCLUSION

In the time ahead, we should work on modernizing physical education classes. This will make it more interesting and creative and students can use their knowledge of IT technology for useful purposes. We know a lot about the advantages of physical activity and nothing can replace it. Rational use of new technologies can greatly facilitate the work of students, increase their engagement and motivation.

ACKNOWLEDGEMENTS

This study was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, and these results are parts of the Grant No. 451-03-68/2020-14/200132 with University of Kragujevac - Faculty of Technical Sciences Čačak.

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