

# Comparison of ground reaction forces during the Basic Step on the Core Board platform at various levels of stability

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*Purpose:* The aim of this paper was to examine and compare the changes of ground reaction forces observed during the Basic Step on the Core Board fitness device at various levels of stability. *Material and method:* The study involved 10 female students. Participants stepped on and off the Core Board 10 times at 3 levels of stability. After completing a series of steps, the Core Board's stability was modified and the participant repeated the whole series. The measurement platform to examine three components of the reaction force (horizontal in the sagittal and frontal planes, and vertical) was used. *Results:* The ground reaction force (GRF) observed on the Core Board, in the vertical and horizontal components is higher at all three levels of stability than on the platform without the device. Significant differences in GRF were observed in the horizontal component in the frontal plane ( $F_z$ ) at all three levels of mobility as well as in impulse, measured on platforms with the device. *Conclusion:* The results on the Core Board training device present highest horizontal ground reaction forces in frontal plane at the highest level of Core Board mobility and this showing little medio-lateral stability and a more reactive way of movement regulation of the participants. As a consequence of the force patterns found it may be suggested that fitness training concepts should focus more possibly higher strains on the locomotor system most likely caused by changed ground reaction force patterns, an idea that has to be further analyzed with more complex measurement approaches.

*Key words:* fitness, Core Board, ground reaction forces

## 1. Introduction

Physical training with various equipment (balls, weights, and resistance bands) makes it possible to work on particular muscles in the whole range of their movement and to practice complicated multi-dimensional sequences [23], [28]. The wide range of activities offer exercises with various equipment, including exercises with the Core Board, that intensifies the classes and makes them more attractive. The Core Board is a moving platform that changes its position after every movement made by the exercising person. This forces the participant to keep their balance, which makes the training more attractive and the exercises more intense. It also activates the core muscles in a wide range of movements: forwards, backwards, sideways, and rotary. The whole platform is unstable; therefore

it develops motor coordination and sense of balance, and balancing on a moving platform results in the muscles becoming flexible and durable. Classes with the Core Board are dynamic and varied, as this equipment can be set up in a number of ways. They also require high levels of focus during exercise. A variety of moves are used during the classes, based mostly on walking, running, and leaping [16], [22]. It can therefore be assumed that the movement structure typical of walking will be observed in the Basic Step, which is a beginner fitness movement. However, using the Core Board for exercises causes the movement to take place both in the sagittal plane and in the frontal plane, with higher instability than in typical human locomotion.

Thanks to systematic physical activity, we can achieve and maintain good physical health [31]. Common knowledge of this fact causes more and more

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people of various ages to attend classes at fitness clubs. This may pose a challenge for the instructor, who has to properly choose the character, form, and intensity of the exercises suitable for the individual needs and requirements of the body in order to avoid overstraining the locomotor system [15], [17], [25], [26]. These exercises should be universal for a wide age group with varied physical capabilities. Among the numerous available objects and aids, the step [1], [20] is largely popular. When using this piece of equipment, the intensity of the exercises is increased by more intense movements, using various moves, increasing the height of the step, and including arm movement [8], [14], [19]. Movement technique during stepping on and off the step is also important [13]. Literature on the subject does not provide data evaluating the indicators under consideration in people who systematically participate in fitness classes employing the Core Board. Publications on the results of different fitness moves on the step seem to be closest to the topic of this paper [4], [10], [18].

Jagusz et al. [7] conducted research on the forces affecting the locomotor system during the basic fitness steps, focusing particularly on the technique where movement is started by setting the foot on the step beginning with the metatarsus or the heel. In the study, two female fitness instructors conducted a series of Step Touch, beginning with the right leg, in two techniques. Strain on the locomotor system was evaluated by analyzing the horizontal and vertical lateral ground reaction forces. The authors concluded that in both techniques of the Step Touch, the vertical ground reaction force is similar to that observed in a person's normal gait. The horizontal component force of a Step Touch is significantly higher than during marching.

Maybury and Waterfield [12] took a similar problem into consideration in their research of ground reaction forces in the Basic Step at three step heights. Twelve females without experience in such exercises participated in the study. By using the Kistler piezoelectric platform, the authors examined the changes of ground reaction forces depending on the height of the step, which was set to 6" (15 cm), 8" (20 cm), and 10" (25 cm).

In the paper by Wysocka et al. [29] two groups, amateurs and fitness instructors, were asked to practice the Basic Step sequences with a movement pace and step height corresponding to typical fitness class conditions. The authors evaluated the kinematic and dynamic values of the movement by means of 3D analysis. In both groups, the vertical ground reaction force during the step-off phase (1.61 BW – instructors,

1.62 BW – amateurs) was higher than when stepping onto the device (1.01 BW – instructors, 1.02 BW – amateurs). The authors of the paper draw attention to two parameters: higher vertical ground reaction force (VGRF) achieved when stepping off the device and the angle of the ankle joint in the transverse plane. This is connected to setting the foot more to the outside, which leads to excessive strain on the outer part of the foot. In the case of the knee angle, statistically significant differences were noticed only in the step-off phase. People who do not exercise regularly were observed to have set their feet on the ground with their knees almost straight. Such a movement technique, paired with high VGRF values during step-off, may cause injuries, not only to inexperienced people, but also to instructors.

Joint movement is one of the mechanisms that decrease mechanical strain on the lower limbs [6]. Santos-Rocha et al. [21] conducted research aimed at gathering the characteristics of the right limb in order to prove the differences between 4 different fitness steps and 4 types of pace dictated during measurements on the step. A group of 18 women experienced in this type of exercises participated in the study. The researchers measured the range of motion and the angular velocity of the hip, knee, and ankle during initial contact with the ground and at the peak value. The results show that in the 4 analyzed types of movement, the participants displayed various kinematic profiles which did not affect the pace of the steps. Nevertheless, the type of the steps and their pace had more effect on the movement range of the knee and ankle, and more influence on the angular velocity in the hip and the knee. The authors' suggestion was that during exercise, people should receive detailed instructions on how to set their feet on the ground and on the step in order to help avoid injuries.

In classes using the step, the participants make enormous numbers of repetitive moves onto and off the device, employing various techniques, paces, and different heights of the step. Improper choice of these elements as well as too much training volume especially in the group of untrained persons may lead to too high ground reaction forces and thereby intensity, likely causing higher risk of fall, ankle or knee joint injuries and in general high strain of the locomotor system. The phase of movement (stepping on or off) and the experience of the participants are also significant. Knowledge of these issues may be useful in choosing the right proportions of the abovementioned factors both for inexperienced participants and for the instructors. The Basic Step used in fitness training has

a structure close to the natural gait. Literature on the subject provides little data on the influence of regular fitness exercises on the quality and quantity of 3D ground reaction forces giving estimates about effects on the human body and on measuring and choosing the intensity of such activities. In particular, information on the effects of Core Board exercises on the aforementioned aspects is scarce.

Thus, the aim of this paper was to examine and compare the changes of ground reaction forces observed during the Basic Step on the Core Board fitness device at various levels of stability as a first step in a bigger project.

## 2. Materials and research methods

### *Research material*

The study involved 10 female students of the 5th year from the University of Physical Education in Warsaw. They were  $24.4 \pm 0.5$  years old, weighed  $56.2 \pm 4.8$  kg, and were  $164.1 \pm 3.1$  cm tall. All of the participants regularly attended fitness classes, but had different levels of expertise in training. Half of the students were certified instructors, while the remainder of the group were at an intermediate level of experience. Before the exercise, the participants were informed about the purpose and method of the research. The measurements were made with optimal attitude of the participants.

### *Research methods*

The measurements were taken in the Central Research Laboratory of the Józef Piłsudski University of

Physical Education in Warsaw. For analyzing the ground reaction forces affecting the joints of the lower limbs during the Basic Step on the Core Board, the researchers used two Kistler dynamometric platforms as measurement tools.

The measurement started when the subject was standing on 1 dynamometric platform and in front of her on platform 2 a Core Board device was placed (Fig. 1A). Starting from this position the subject stepped on and off the Core Board 10 times in 1 series at one level of stability (Fig. 1B, C). Platform without Core Board (1) registered ascending and descending phases from device (placed on the second platform) and platform with Core Board (2) also registered ascending and descending phases but from the platform with Core Board device placed on it. After completing first series of steps, the Core Board's stability was modified and the participant repeated the whole series (10 steps) on the second and third level of stability of the device (each person examined performed 10 Basic Steps in 3 series, in total). Ground reaction forces were recorded separately for each series and these began from starting position (Fig. 1A). Three levels of the device stability mean that device moves in all directions and planes at first level as an easy, second-middle and third is difficult – the most movable and unstable level. The pace of the exercise was dictated by music and oscillated around 118–138 BPM (beats per minute).

The researchers used the measurement platform to examine three components of the reaction force (horizontal in the sagittal and frontal planes, and vertical). On the basis of the progress of these forces, they calculated the impulse. The data was later used to analyze the variance of repetitive results in the STATISTICA software. The analysis took anthropometric factors, such as the mass and height of the participants, into consideration.

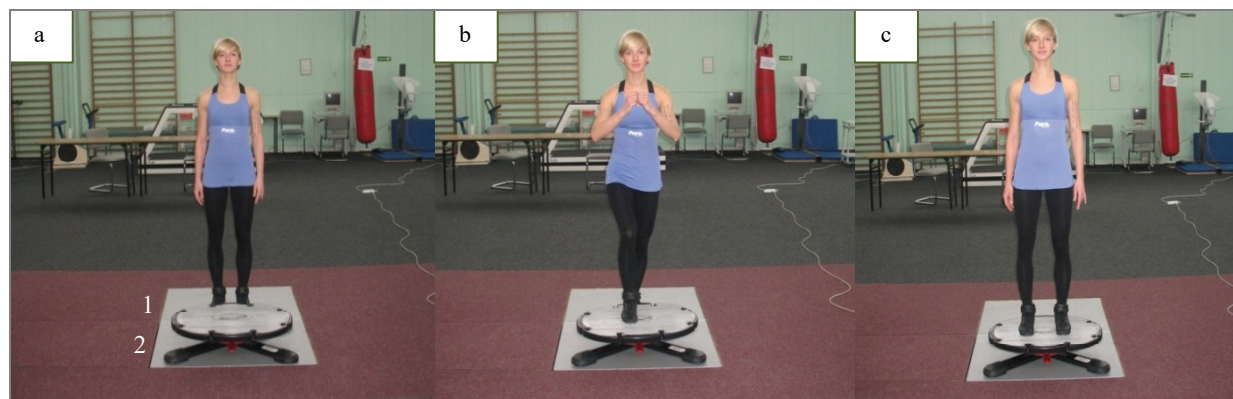


Fig. 1. Phases of Basic Step performed on Core Board  
(1 – platform without Core Board; 2 – platform with Core Board)

### 3. Research results

Examples of ground reaction forces measured with the use of the BioWare software can be seen in Fig. 2. The analysis included the average values of the peak vertical and horizontal component forces of the ground reaction forces in the 6 middle steps (Fig. 3). The impulse was calculated on the basis of the progress of the ground reaction forces in time (Fig. 4).

Figure 3a presents the average values of the peak horizontal component of the ground reaction forces in the frontal plane (Fz). There is not much deviation, the forces oscillate at about 45 [N] regardless of the Core Board's stability level. An analysis of the group's average results shows that the largest ground reaction force (Fz) was observed on a platform without the Core Board at its highest stability level (51 [N]). As the stability of the Core Board decreases, the horizontal component force in the frontal plane (Fz) declines. It can be concluded that the participants stepping off the Core Board (Fig. 3a) at a lower stability level worked with smaller ground reaction forces in the frontal plane.

The peak horizontal ground reaction forces in the sagittal plane (Fx) in the group display an opposite regularity with small deviations between the results. The lower the stability of the Core Board, the higher the horizontal component force in the sagittal plane. The observed tendency of the horizontal component force to rise with the Core Board's instability may be a result of the larger forces in the sagittal plane, as these forces affect motor coordination and sense of balance. While analyzing the results, we need to take into consideration that the Basic Step is made in the sagittal plane; therefore, it is based on the same phases as walking and running. The values of the horizontal force in both planes are similar regardless of the Core Board's level of stability.

Figure 3b presents the approximate values of the horizontal component force in the frontal plane (Fz) measured during the Basic Step on the platform with Core Board. The differences between the average values at different levels of the device's stability were not statistically significant. Furthermore, there is a slight tendency of the horizontal component force in the frontal plane to rise when the stability of the Core Board decreases.

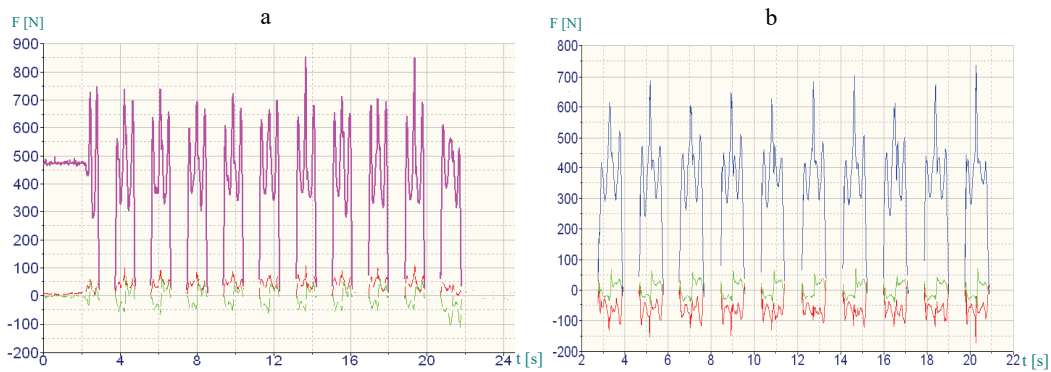


Fig. 2. Examples of ground reaction forces in the vertical (y) and horizontal components (in the coronal (z) and sagittal (x) plane) measured during Basic Step on platform without (A) and with (B) Core Board device

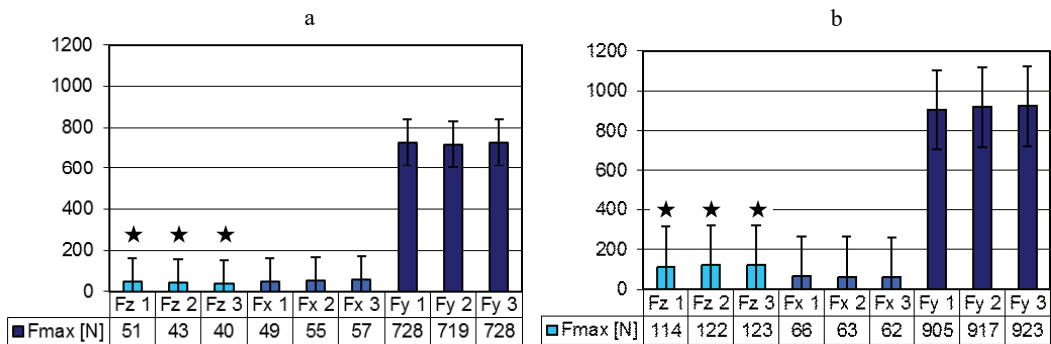


Fig. 3. The average values of the peak of the ground reaction forces [N] on platform without (a) and with (b) Core Board device  
 ★ Statistically significant difference of the horizontal component of ground reaction force in the frontal plane (Fz) measured on platform with Core Board in comparison to platform without Core Board ( $p \leq 0.01$ ).

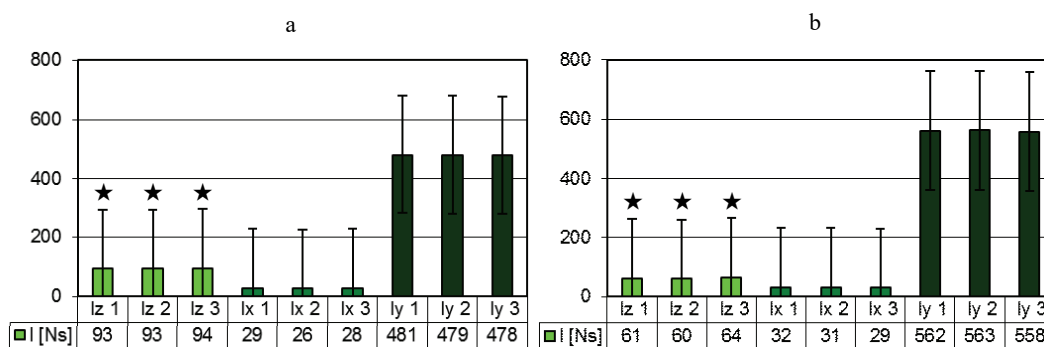


Fig. 4. The average values of the peak of the impulse [Ns] on platform without (A) and with (B) Core Board device

The average values of the horizontal component of the ground reaction force in the sagittal plane ( $F_x$ ) among the women in the study group oscillate around 63 [N]. It is worth noticing that the highest values of the forces in the sagittal plane were achieved at the highest levels of the device’s stability, whereas the lowest values were achieved at the lowest levels of stability. There is a clear difference between the vertical component force ( $F_y$ ) and the horizontal component force. The vertical component force is much higher than the horizontal one (which is natural when walking) during the Basic Step, regardless of the Core Board’s level of stability. The analysis of the results has also shown a slight tendency of the peak values to rise as the stability of the Core Board decreases.

The differences between the particular components of the ground reaction forces at different levels of the device’s stability were small and statistically insignificant for both platforms.

A comparative analysis was made of the average peak values of the horizontal and vertical components of the ground reaction force in the sagittal and frontal planes for both the platforms. Large differences were observed in the horizontal component force in the frontal plane at all three levels of mobility. The differences are statistically significant.

Statistically significant difference of the impulse in the horizontal component of ground reaction force in the frontal plane ( $F_z$ ) measured on platform with Core Board in comparison to platform without Core Board ( $p \leq 0.05$ ).

The impulse was calculated on the basis of the reaction forces’ progress in time. Most of the impulse values of the horizontal component force both in the sagittal ( $I_x$ ) and frontal ( $I_z$ ) planes do not significantly change depending on the Core Board’s stability level (Fig. 4a). The impulse of the vertical component force ( $I_y$ ) is significantly higher, but does not vary much depending on the device’s stability. The smallest impulse values were observed in the horizontal compo-

nent of the ground reaction forces in the sagittal plane. This means that the highest values for platform without device were achieved by the participants in the horizontal and vertical component forces in the frontal plane.

On the platform with the Core Board, there were also no significant differences between the values of the horizontal component force depending on the Core Board’s mobility level (Fig. 4b). The vertical component ( $I_y$ ) of the impulse reached the highest values.

The average values of the peak impulse of the horizontal and vertical component forces in the sagittal and frontal plane on the platform without and with Core Board were compared. There was one statistically significant difference of the horizontal component force’s impulse in the frontal plane at all three levels of mobility ( $p \leq 0.05$ ).

## 4. Discussion

Fitness clubs currently offer various kinds of active leisure [3], [24]. As many people systematically attend particular classes, it is important to examine the effects of those activities on the human body [2], [9], [27]. The result is a need to search for new methods that would reliably characterize the influence of the physical strain in different kinds of active leisure exercises on the body’s functioning [5], [11], [30]. In connection to this research direction, this paper attempts to measure the ground reaction forces during exercise on the Core Board. Literature on the subject does not provide data corresponding to the data gathered in the analyses conducted on the Core Board platform, which focused on the indicators under consideration in people systematically attending fitness classes. Therefore, the results achieved while performing different fitness moves on a step were used as reference, due to their being the most approximate to

Table 1. The average values of the ground reaction forces [N] in the vertical and horizontal components (in the frontal and sagittal plane) presented by the relative ratio “BW”

Ground reaction force [N] (BW)	Platform without Core Board			Platform with Core Board		
	Stability level Core Board			Stability level Core Board		
	I	II	III	I	II	III
F <sub>y</sub>	1.18–1.45	1.18–1.37	1.20–1.37	1.46–2.12	1.47–2.17	1.47–2.10
F <sub>z</sub>	0.03–0.12	0.04–0.11	0.04–0.10	0.16–0.28	0.17–0.28	0.18–0.27
F <sub>x</sub>	0.06–0.13	0.07–0.15	0.07–0.14	0.09–0.17	0.08–0.17	0.08–0.17

the research topic. In order to compare the results of this research to the works of other authors, the observed ground reaction forces were presented by the relative ratio “BW” (Table 1).

The progress of the vertical component of the ground reaction force measured on the Core Board platform is similar in values to natural gait. It oscillates at levels similar to the peak values observed in the cited works. The results achieved in this study show that the vertical component of the ground reaction forces observed on the Core Board is higher than in the case of the works of other authors, who used a step. The values range from 1.5 to 2.1 BW, but they remain within the values observed in natural gait. Increasing the mobility of the Core Board causes a slight rise in pressure in the vertical component force, similar to the values observed during running. This regularity may be caused by a higher dynamic of movement, which is in a way enforced by an unstable platform.

When comparing the data gathered with data from the literature, we observed that the values of the horizontal component of the ground reaction force are similar to those presented by Jagusz et al. [7] and do not deviate significantly from values typical of walking. Jagusz et al. examined strains on the locomotor system during a Step Touch. The resulting values of the horizontal component in the frontal plane are much higher for the examined fitness move and vary from 0.2 BW to 0.31 BW. The values observed in this study for the horizontal component force (Table 1) on the Core Board are close to the data of the abovementioned authors at all levels of stability (0.16 to 0.28 BW). The ground reaction forces without the Core Board are comparable to the relative ratio of walking (0.03 BW).

The horizontal component force in the frontal plane observed during walking is ineffective to natural human locomotion. This is probably why stepping onto the Core Board with the Basic Step requires a person to turn their feet to the outside of the line marked by the movement direction, similar as during a Step Touch.

Significantly higher parameters of the horizontal component of the ground reaction force in the frontal plane when compared to the phases of walking may indicate a higher risk of injury, especially to the ankle, as suggested also by Jagusz et al. [7].

Maybury and Waterfield [12] analyzed a similar aspect of exercise on the step. They observed significant differences in the ground reaction force depending on the height of the step. Changing the height of the step from 6 to 8 inches and from 6 to 10 inches caused a considerable rise in the ground reaction force. The authors drew conclusions important for practical aerobics classes. They suggested that beginners should exercise at the lowest height of the step in order to avoid sudden overstraining of the locomotor system, mostly the joints of the lower limbs.

The vertical component of the ground reaction force observed during the Basic Step on the Core Board are higher than on a step, but remain within the value range typical of walking. We can therefore suppose that vertical forces affecting the body during the Basic Step on the Core Board do not cause considerable strain on the locomotor system.

## 5. Conclusions

The ground reaction force observed on the platform with the Core Board, both in the vertical and horizontal components are higher at all three levels of stability than on the platform without the Core Board. However, significantly higher ground reaction forces were observed in the horizontal component in the frontal plane (F<sub>z</sub>) at all three levels of mobility indicating lower medio-lateral stability and more reactive way of movement regulation. As a consequence of these force patterns it may be suggested that during fitness training more attention should be paid to possible higher strains on the locomotor system most likely caused by changed ground reaction force patterns which has to be further analyzed. No statistically significant differences were observed between corre-



sponding forces and impulse at different levels of the device's stability. The observation is that the stability level had no relevant influence on the mechanical parameters of the ground reaction forces. However, when comparing the relative values of the ground reaction force to the findings of different authors, the results turned out to be higher on the Core Board than on the step. Statistically significant differences in impulse, measured on platforms with and without the device, were only observed in the horizontal component force in the frontal plane (Fz). Statistically significant higher values were observed on the platform with Core Board at all levels of stability. The results of this study may indicate a problem connected to the strains experienced during exercise with the Core Board, which is a new fitness device. They may also be a hint to the direction of further research including synchronously 3D force measurements, pressure distribution insoles and 3D kinematics. It seems that the results achieved should encourage more detailed research. Experiments on the connections between the above fields have just begun and offer a wide area for examination, especially in reference to fitness training.

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