

Balance a few years after total hip replacement

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Research article

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Abstract

Background: The aim of the study was to conduct a long-term evaluation of whether total hip replacement permanently affects the quality of postural reactions and body balance. **Material and methods:** The unilateral Total Hip Replacement (THR) group consisted of 30 subjects (mean age: 69.4). The control group consisted of 30 healthy subjects (mean age: 68.8). The force platform and functional tests such as Timed Up and Go, 3m walk test, Functional Reach Test, 30s Chair Stand Test, Step Test and Berg Balance Scale were used to assess dynamic balance. **Results:** Subjects from the study group exhibited significantly increased time ($p=0.002$) and distance ($p=0.012$) in the tests performed on the force platform compared to the control group. We also observed worse balance and functional test scores in the THR group: Timed Up and Go test ($p<0.001$), 3m walk test ($p<0.001$), Functional Reach Test ($p=0.003$), 30s Chair Stand Test ($p=0.002$) and Step Test (operated leg: $p<0.001$, non-operated leg: $p=0.002$). The results obtained in the Berg Balance Scale tests were not significantly different between the groups ($p=0.597$). **Conclusions:** Our research shows that total hip replacement permanently impairs patients' dynamic balance and functionality in certain lower-extremity activities. **Keywords:** balance, total hip replacement, gait, muscle strength

Introduction

Years of suffering from hip osteoarthritis is destructive to the joints, which eventually results in asymmetrical loading of lower extremities, dysfunctional static balance and, as a consequence, dysfunctional dynamic balance and gait dysfunctions [1]. Such patients also show deficits in muscle strength, function and physical activity compared to healthy adults [2]. Therefore, such persons face increased risk of falls [3]. In such cases total hip replacement (THR) is generally the treatment method of choice [4]. It is worth pointing out, however, that undergoing the surgery later in the history of functional decline has been associated with worse outcomes [5].

The procedure itself leads to decreased amounts of proprioceptors located in the articular capsule and muscles, while postoperative pain impedes patient functionality [6, 7]. As a result, activities which entirely rely on the performance of lower extremities are temporally impaired. One consequence might be deteriorating postural control and dynamic balance, which determine proper gait quality. Therefore, it is paramount that physical procedures are applied as fast as possible in order to limit the degree of lower limb dysfunctions, improve performance on tasks such as stair climbing, fast walking, and balance and return patients to full daily activity [8, 9]. Patients often enjoy decrease in pain, improved range of movement and the level of function recovery after surgery [2, 10]. However, many reports reveal patients' dissatisfaction with their ability to perform social and domestic activities and the persistence of functional limitations [11, 12].

Indirect evidence for improvements in THR patients with regard to some functions (gait, rising from chair, improved life quality) was provided by the work of O'Connell et al. and Vissers et al. [13, 14]. Nonetheless, few projects have focused on the quantitative dimension of postural control examination [15, 16, 17]. A

question arises as to whether the discussed postoperative dysfunctions have a tendency to subside over time?

Assessment may include static and dynamic balance. In numerous studies both static and indirectly dynamic balance is examined, especially one year post-surgery [10, 18]. Such intermediate assessment concentrates on gait, because gait instability has been identified as a relatively consistent risk factor for falls. In order to identify those at risk of falls, the majority of screening programmes comprise gait and balance assessment [19]. We believe such procedural approach is a simplification.

Test results of THR patients are compared against their performance before surgery and not against results of a control group consisting of age-matched people without prosthetic implants [18]. Review of subject literature shows that studies investigating dynamic balance longer periods of time post surgery are scarce [20, 21].

Some researchers observed that after THR many patients continue to show abnormal gait patterns compared to preoperative levels and healthy subjects. Reduced walking ability and muscle weakness may be a reason for decreased mobility [11]. Also balance and proprioceptive deficits are often persistent after THR. Balance impairments limit functionality, hinder activities of daily living (such as self-care) and lead to altered movement patterns and difficulties in walking and maintaining postural control [22]. It is also associated with an increased incidence of falls [23]. Our research investigates the quality of postural control in dynamic conditions in THR patients. For this purpose, we conducted a posturographic examination in dynamic conditions and we applied a set of selected clinical tests used for assessing balance impairments and risk of falls.

Methods

Subjects

The study included patients treated at the Outpatient Rehabilitation Ward of Wiktor Dega's Orthopaedic and Rehabilitation Clinical Hospital at Poznan University of Medical Sciences, Poland. Patients from both groups were treated in the clinic for four weeks. The assessment of balance was performed only once at the beginning of the rehabilitation process.

The THR group included 30 individuals (25 women and 5 men) who had undergone unilateral total hip replacement following advanced osteoarthritis. The patients had unilateral anterolateral THR. The average time of the postoperative period was 5.3 years ($SD=4.0$). The control group comprised 30 people (25 women and 5 men) without hip endoprosthesis who did not report any pain or limited range of motion in joints. Due to the age of patients, those qualified for the group showed I^o radiological changes in hip joints as measured on the Kellgren-Lawrence scale. The THR group and the control group were age and sex matched. Average age of a person with endoprosthesis was 69.4 ± 6.2 , whereas for healthy

individuals it was 68.8 ± 5.9 . No statistically significant differences in age, height, weight and the BMI index were found between the study and the control group (Table 1). There was also no significant difference in abductor muscle strength measured with the Manual Muscle Test between the two groups ($p=0.649$).

Table 1 near here

The inclusion criteria for both groups were as follows: moving without crutches, age above 55 years and scoring at least 9 points on the AMTS scale (Abbreviated Mental Test Score). The applied AMTS scale [24] was supposed to help identify and exclude from the study individuals with reduced cognitive functions and decreased ability to concentrate. The criteria for exclusion for both groups were diseases affecting the balance such as: vestibular problems, neurological conditions (hemiplegia, peripheral neuropathy, stroke, Parkinson's disease, SM), muscles diseases, rheumatic diseases (rheumatoid arthritis, ankylosing spondylitis, psoriatic arthritis), sciatica, operations in the area of the spine and lower limbs (knee arthroscopy with ACL reconstruction or meniscectomy, total knee replacement, total hip replacement in both extremities, osteotomy or arthrodesis). All subjects expressed written consent to participate in the study. The study was conducted in compliance with the Declaration of Helsinki and with the approval of the Bioethics Committee of Poznan University of Medical Sciences (reference number 949/14). Data were anonymised before analysis.

Experimental procedures and instruments

Dynamic balance and functional mobility were assessed with Metitur's Good Balance force platform and the following tests: Timed Up and Go test, 3m walk test, Functional Reach Test, 30s Chair Stand Test, Step Test and Berg Balance Scale.

Dynamic test on force platform

The dynamic test on the force platform was based on the principle of biofeedback. It was performed on 1 board (including "path") and with different sensitivity of platform (B100 and B60). The board showed "paths" for displacement of centre of feet pressure (Figure 1). Patients could observe certain position of the centre of feet pressure (COP) on the screen. It was visualized as a cursor and the tasks were to achieve the targets successively displayed on the screen during displacement of the body. The subject's position during dynamic tests was upright with feet placed parallel and 20 cm apart [25]. The B100 scale was characterized by a greater distance to designated targets than the B60 scale. Before measurement, volunteers were informed that velocity (time) on the B100 board and accuracy (distance) on the B60 board were equally important.

In both cases values were recorded for task performance time (s), distance of COP displacement (mm), COP displacement distance in the sagittal plane (Y) and COP displacement distance in the frontal plane (X).

Figure 1. B100 board on a force platform.

Timed Up and Go (TUG)

The TUG test is recommended as a routine screening tool for risk of falls by the American Geriatric Society and British Geriatric Society [26]. During the test, patients were to rise from a chair, walk a distance of 3 meters, make a turn of 180 ° having crossed a designated line and return to the chair. Recording the time of performing the task was initiated by the “start” command and stopped the moment a patient returned to the sitting position with the back resting against the chair. Patients were instructed to do the task as quickly as possible, but at the maximum speed at which the patient could walk safely without running [27, 28]. Each participant completed three trials. An average value from all three trials was recorded as study data for further analyses.

3m walk test (3m)

The test was conducted to assess gait speed [29]. Slow gait is associated with risk of falling [30]. Patients were instructed to stand with their toes touching the start line and walk fast beyond the taped finish line. The time from the moment their foot crossed the start line to the moment their both feet crossed the stop line was measured. Each participant completed three trials. An average result from all three trials was recorded as study data for further analyses.

Functional Reach Test (FRT)

The FRT is a popular method of measuring the dynamic balance of the elderly and is useful as a predictor of the risk of falling and a decline in function of the elderly. During test, the patient was standing by the wall with their feet shoulder-width apart, one shoulder flexed at 90° and the other arm on the side. A ruler was attached to the wall. Patients were instructed to reach their maximal distance (in centimetres) without moving their feet or losing balance and come back to the standing position. If subjects raised a heel or took a step during testing, the trial was repeated. Each participant completed three trials. An average distance for all three trials was recorded as study data for further analyses [31].

30s Chair Stand Test (CST)

Low levels of body strength are the primary cause of both balance problems and falls in the elderly population. CST measures lower body strength and relates it to the most demanding daily life activities (e.g., climbing stairs, getting out of a chair or bath tub or rising from a horizontal position) [31]. The test consists of standing up and sitting down from a chair as many times as possible within 30 seconds. Initially, subjects were seated on the chair with their arms folded across the chest and with a back in an

upright position. They performed only one trial and started it after a command. A standard chair with armrests was used. All patients performed the test using the same chair [32, 33].

The Step Test (ST)

The step test developed as assessment of dynamic standing balance after stroke. However, we have incorporated it into our study, since in our clinical practise the test is often applied when THR patients learn to walk on stairs. When tested, subjects were instructed to place one foot onto a 7.5 cm high step and then take it back down to the floor repeatedly as fast as possible. The score is the number of steps completed in the 15-second period for each lower extremity [34]. Both sides were tested two times, with the THR group completing the test first with the operated leg (ST O) and then the non operated leg (ST N). Scores for each lower extremity were recorded separately. Better results were recorded as study data for further analyses. We calculated a reference value in the control group (ST C), which is a mean representing all tasks conducted with the left and right limb.

Berg Balance Scale (BBS)

The Berg Balance Scale (BBS) is currently the most commonly used clinical test for assessment of functional balance in older adults, which matches our study group. Subjects did 14 different tasks including static tests with different feet positions and functional balance control tasks including transfer, getting up and sitting on a chair, reach, turning and stepping. The BBS tests performance on levels from 0 (can't perform) to 4 (normal perform) and can give a total score of 56. Higher scores on the BBS indicate better balance. A total score obtained in 14 trials was recorded for further analyses [35].

Statistical analysis

Data were analysed with the Statistica version 13.1. Demographic data and clinical characteristics are presented as means, standard deviations (SD), median, minimum (min) and maximum (max). The Shapiro-Wilk test was used to assess the normality of the distributions in the test score. To compare the differences between the THR group and the control group, we applied the independent t-test, the Welch test or the non-parametric U Mann-Whitney test depending on which test assumptions were met. P-values less than 0.05 were considered statistically significant.

Results

Dynamic tests on the force platform

There were statistically significant differences in the time and distance of COP displacement in saggital planes (Y) between the study and the control groups in B60 board tests. The values for both of these parameters were found to be higher in the study group (Table 2).

Subjects from the research group performed the task slower and demonstrated greater COP displacement.

However, there were no statistically significant differences in B100 board test results (time and distance) between the study and the control group.

Table 2 near here

Functional test results

There was significant difference in TUG, 3m, FRT and CST between groups (Table 3). Both tests assessing gait in patients after total hip replacement showed that they completed the task slower than members of the control group. Completing the TUG test by an individual from the study group took on average 1.64 seconds longer than in the control group ($p<0.001$), whereas the walking time over the distance of 3 meters was 0.55 seconds longer. In the FRT trial the reach distance of THR patients was on average 3.9 cm shorter than of the control group ($p=0.003$). Furthermore, considerable differences were observed in the CST, where members of the control group did more repetitions than subjects in the study groups ($p=0.002$). We did not find statistically significant differences in the results of the BBS test between the study and the control group.

Table 3 near here

Step Test results of individuals with prosthetic implants differed significantly from results in the control group. The differences were present when comparing to the control group (average 16.3) both the operated limb (mean 13.2; $p<0.001$) and the limb without a prosthetic implant (mean 13.5; $p<0.002$) in both cases people with total hip replacement conducted fewer repetitions (Table 4). To summarize, task performance by THR patients was worse compared to the control group.

Table 4 near here

Discussion

Balance control is required not only to maintain postural stability but also to ensure safe mobility-related activities during daily life, such as standing while performing manual tasks, rising from a chair, walking and turning [3, 36]. The persistence of degenerative hip joint disease produces in most cases progressive deterioration of postural control, which is associated with [10] decreased range of motion in the hip joints, reduced muscle strength and pain felt during walking or running. Due to post-operative physical rehabilitation it is possible to considerably improve motion in the affected hip, increase muscle strength of the pelvic girdle and the thigh on the operated side [37] which will enable pain-free movement and later on a return to active professional, social and family life. Subject literature shows few objective assessments of postural balance over the course of degenerative hip joint disease and hip joint replacement [10]. Additionally, our review revealed that if such type of assessment was used, it would be performed not a long time after the surgical procedure, and it would also be based on a testing method whose availability in clinical practise to other doctors of rehabilitation and physical therapists is limited

[15, 17, 18]. Our study of the quality of dynamic balance used single-board force platform [25] as well as functional tests recommended by other researchers [20, 26-35] for evaluating the quality of dynamic postural control or assessing the risk of falling. The force platform test that used the B60 board (see Methods) showed that people with THR had significantly worse dynamic balance control in the sagittal plane ($p=0.012$) and were slower to complete the task ($p=0.002$) compared to healthy individuals in the control group. There were no studies on dynamic balance and THR found in relevant subject literature that would use a test methodology similar to ours. The prevailing test used such clinical cases is computerized dynamic posturography. Among others, the method tests a patient's ability to maintain balance under different conditions of sensory system stimulation (Sensory Organisation Test-SOT) as well as reflexive abilities of postural control in response to sudden changes in the positioning of a supporting surface (Motor Control Test-MCT) [15].

Calò et al. [15] did not find significantly worse results in THR patients compared to the control group both in SOT and MCT four months after THR. They suggested normal postural control, symmetrical responses in THR patients and irrelevant role of intrascapular proprioceptors in maintaining balance [15]. Similar studies were conducted Nallegowda et al. [17]. They proved, however, that dynamic balance and gait differed significantly between THR group and healthy subjects of comparable age and sex. In the SOT with difficult tasks, the THR group needed more sensory input from vision and vestibular sense, and there was a delayed motor response. They also did not observe any proprioceptive deficits in patients after THR compared with the healthy group.

The force platform tests are complemented with measurements of dynamic balance conducted with simple and commonly used clinical tests. The first applied test was the Functional Reach Test (FRT); it includes an essential motion often performed in daily life [38]. FRT test results show that people after THR achieve a reach distance that is on average 3.9 cm shorter than in the control group. Lavigne et al. [21] saw similar results when assessing patients before surgery and then 3, 6 and 12 months after. The THA group was not able to reach control subjects' values for the functional reach test at any follow-up evaluations. Chang et al. [20] also used FRT and similar intervals to measure patients' abilities, but there was no control group to compare the results. They suggested that functional reach distance tended to improve gradually after surgery, reached the maximum distance, and decreased at 1 year postoperatively indicating that the somatosensory and neuromuscular function around the hip joint did not recover progressively or completely within 1 year.

Rising from a chair is an important metric of biomechanical recovery after THA. This task requires greater muscle strength and produces higher joint forces than walking and stair climbing. It is a fundamental daily activity performed approximately 60 times per day by healthy adults [39]. The 30-Second Chair Stand Test assesses the number of times a person can stand and then sit in a chair in 30 seconds [40]. In our study, people after THR did fewer repetitions compared with the control group ($p=0.002$). Vissers et al. [14] observed that six months post-THA patients rose from a chair faster compared to baseline, but they needed more time compared to the control group. These authors, however, based their study on a different, more complex measurement method. Patients and control group were tested at home with an

accelerometry-based Activity Monitor, and for each patient 20 chair rising movements during the measurement period were randomly selected by a computer program and analysed [14].

The Step Test (ST) shows evidence of validity, since the Step Test scores correlate with other clinical tests of balance and mobility. Until now the test was used, among others, in assessments of post-stroke patients [34]. Literature review did not find any studies that would apply the Step Test for assessing balance in THR patients with the use of study methodology analogous to ours. According to Mercer et al. the Step Test, besides requiring balance during lower limb movement in standing, reflects lower limb motor control and coordination [34]. From the biomechanical and clinical point of view when the individual steps with the "operated foot", the operated lower extremity must move quickly in flexion and reverse movement direction. When the individual steps with the non-operated foot, the operated lower extremity must be stable in extension, supporting full body weight. In our tests, patients on average did 3 repetitions less with both the operated ($p<0.001$) and non-operated limb ($p=0.002$). The Step Test results were significantly lower than in the control group, which may indicate deficits in dynamic balance and coordination.

To determine the quality of balance, we also used the BBS test, which comprises both static (maintaining position) and dynamic tasks. It is the only test where we did not find significant differences between the groups. Ellison et al. [41] also did not find significant differences in a group of patients approximately 6 months post-THA compared to a group of age- and gender-matched healthy subjects with no hip replacement. However, scores on a subset of 4 more difficult tasks from the BBS were significantly lower in the group of subjects with THA (turning to look behind while standing, turning 360°, placing each foot alternately on a step while standing unsupported and standing unsupported with one foot in front). Chang et al. also based his balance assessments on this testing method. The authors, however, applied the test to evaluate progress in functional abilities of patients by comparing their result prior and post operation. Authors suggested that BBS decreased significantly at 2 weeks and improved gradually, reaching the highest score of 53.2 ± 1.9 at 6 months after surgery [20].

Gait assessment is an important measure of postoperative outcomes after THA because gait is an important indicator of functional recovery [42]. As mentioned above, correct dynamic balance is a major factor in THR patients' gait quality. Analysis of subject literature showed that gait assessment in patients after THR was performed using different tools and tests such as: TUG, Dynamic Gait Index, the GAITRite® system, 6 minute walk test, gait laboratory, three-dimensional gait analysis [2, 21, 42, 43]. Abnormal gait was found both in the period following surgery as well as a few years later. What is important is that in the latter case, the condition was not associated with pain, limited motion or loss of muscle strength in the operated extremity [42]. For instance, Kolk et al. performed a systematic review and reported that walking speed and step length were reduced in the THR group compared to controls at longer-term follow-up, but not at the short-term follow-up [44]. These findings are consistent with those reported by Agostini et al. [45] who observed some gait abnormalities one year after surgery such as a higher percentage of atypical cycles, a prolonged heel contact, a shortened flat foot contact, a reduced hip dynamic range of motion and abnormal timing in the muscle activation patterns (tibialis anterior, gastrocnemius lateralis,

biceps femoris, gluteus medius). Bahl et al reached similar conclusions [46]. At 12 months after surgery, the patients demonstrated deficits compared with healthy individuals in walking speed, stride length, single limb support time and sagittal plane hip ROM. Importantly, Vissers et al. [14] observed that six months after surgery patients walked faster compared to baseline and walked as fast as healthy controls.

In our tests, gait assessment was an indispensable supplement of dynamic balance diagnostics and was performed using the TUG test and the 3 m test. The TUG test is a reliable and valid test for quantifying functional mobility and is quick to perform, requires no special equipment or training and is easily incorporated into medical practice routine [27]. It is also used to assess increased risk of falls in elderly people. In both test people after THR showed worse results than healthy controls, which means abnormal gait patterns are present as long as a few years after being operated, and indirectly it shows these people suffer from dynamic balance deficiencies. Similar to our study, Guedes et al. [41] evaluated patients a few years after surgery and observed that elderly subjects with a history of THR had changes in gait parameters and lower performance in TUG test even 2.6 ± 1.3 years after surgery, which suggests functional impairment.

Conclusion

Our results demonstrate that even a few years after operation THR patients exhibit balance deficiencies compared with people of the same age without a prosthetic implant. We think that short functional tests such as TUG, 3m walk test, Functional Reach Test, 30s Chair Stand Test and Step Test may be used in functional assessments of patients a few years after they underwent total hip replacement.

Limitations

The calculation of the sample size before the start of the test has not been performed so it can be considered as a pilot study.

Abbreviations

AMTS: Abbreviated Mental Test Score; BBS: Berg Balance Scale; COP: centre of feet pressure; CST: 30s Chair Stand Test; FRT: Functional Reach Test; ST: The Step Test; THR: Total hip replacement; TUG: Timed Up and Go; X: frontal plane; Y: sagittal plane; 3m: 3m walk test

Declarations

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Availability of data and materials

Data are available on request from the authors.

Conflicts of interest

The authors declare that there is no conflict of interest.

Authors' contributions

AW and PL participated in the design of the study and data interpretation. AW carried out data collection and data analysis. AW and PL drafted the manuscript. Both authors read and approved the final manuscript.

Ethics approval and consent to participate

All subjects expressed written consent to participate in the study. The study was conducted in compliance with the Declaration of Helsinki and with the approval of the Bioethics Committee of Poznan University of Medical Sciences (reference number 949/14).

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Tables

Table 1. Demographic data of participants

variable	THR group		control group		
	mean±SD	min-max	mean±SD	min-max	p
age	69.4 ± 6.2	59 - 83	68.8 ± 5.9	60 - 83	0.717 ^a
weight (kg)	74.8 ± 15.4	55 - 115	70.3 ± 10.9	50 - 92.5	0.739
height (cm)	164.5 ± 8.5	152 - 190	164 ± 7.0	152 - 182	0.455
BMI	27.5 ± 4.3	20.8 - 41.2	26.1 ± 3.2	18.8 - 31.2	0.149 ^a

t-student test^a or Mann-Whitney test

Table 2. Results of dynamic test from the B100 and B60 boards obtained by the THR and the control group

parametr	group	B100				B60			
		mean ± SD	min - max	median	p	mean ± SD	min - max	median	p
time (s)	THR	16,81 ± 5,81	8,26 - 35,67	14,81	0,375	17,96 ± 4,32	10,84 - 30,01	18,31	0,002
	control	15,12 ± 3,41	9,80 - 22,16	14,02		14,69 ± 2,51	11,32 - 21,27		
	THR	1239,6 ± 297,1	840,4 - 1876,7	1152,9	0,473	1021,5 ± 287,4	601,3 - 1768,7	1000,5	0,065 ^c
	control	1164,8 ± 205,9	859,4 - 1792,6	1142,0		898,0 ± 214,9	563,9 - 1325,4	912,8	
distance Y (mm)	THR	768,8 ± 153,4	510,4 - 1112,9	748,1	0,557 ^a	622,6 ± 137,1	386,3 - 886,6	608,9	0,012
	control	747,8 ± 119,8	574,0 - 1117,2	712,8		538,6 ± 110,8	346,6 - 823,0	524,1	
	THR	790,0 ± 250,3	451,4 - 1331,9	720,2	0,429	656,2 ± 245,5	291,1 - 1312,2	617,8	0,379
	control	721,1 ± 181,1	464,1 - 1434,1	709,9		587,1 ± 192,6	289,9 - 924,4	564,8	

t-student test^a or Mann-Whitney test

Table 3. Results of functional tests obtained by the THR and the control group

test	group	mean ± SD	min - max	median	p
TUG (s)	THR	9.53 ± 1.77	6.43 - 13.46	9.29	<0.001
	control	7.89 ± 0.80	5.84 - 9.73	7.89	
3 m	THR	3.18 ± 0.48	2.31 - 4.34	3.24	<0.001^b
	control	2.63 ± 0.27	1.96 - 3.16	2.66	
FRT (cm)	THR	34.0 ± 5.9	24.3 - 51.3	34.1	0.003^a
	control	37.9 ± 3.5	31.0 - 45.0	37.7	
CST	THR	11.1 ± 3.5	5 - 19	11	0.002
	control	14.0 ± 3.9	9 - 30	13	
BBS	THR	55.03 ± 1.90	48 - 56	56	0.597 ^b
	control	55.53 ± 1.04	52 - 56	56	

t-student test^a, Welch test^b or Mann-Whitney test

Table 4. Results of Step Tests obtained by the THR and the control group

test	group	mean ± SD	min - max	median	p
ST	THR ST O	13.2 - 3.2	7 - 22	13	<0.001
	THR ST N	13.5 - 3.7	8 - 23	13	0.002
	control ST C	16.3 - 2.9	9 - 22	16.5	-

t-student test

Figures

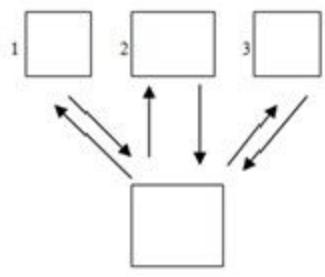


Figure 1

B100 board on a force platform