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Original article

Predicting Ability of Dynamic Balance in Construction Workers Based on Demographic Information and Anthropometric Dimensions

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ABSTRACT

Background: Difficulties in walking and balance are risk factors for falling. This study aimed to predict dynamic balance based on demographic information and anthropometric dimensions in construction workers.
Methods: This descriptive-analytical study was conducted on 114 construction workers in 2020. First, the construction workers were asked to complete the demographic questionnaire determined in order to be included in the study. Then anthropometric dimensions were measured. The dynamic balance of participants was also assessed using the Y Balance test kit. Dynamic balance prediction was performed based on demographic information and anthropometric dimensions using multiple linear regression with SPSS software version 25.
Results: The highest average normalized reach distances of YBT were in the anterior direction and were 92.23 ± 12.43% and 92.28 ± 9.26% for right and left foot, respectively. Both maximal and average normalized composite reach in the YBT in each leg were negatively correlated with leg length and navicular drop and positively correlated with the ratio of sitting height to leg length. In addition, multiple linear regressions showed that age, navicular drop, leg length, and foot surface could predict 23% of the variance in YBT average normalized composite reach of the right leg, and age, navicular drop, and leg length could predict 21% of that in the left leg among construction workers.
Conclusion: Approximately one-fifth of the variability in the normalized composite reach of dynamic balance reach among construction workers using method YBT can be predicted by variables age, navicular drop, leg length, and foot surface.

1. Introduction

Falling is an important hazard that threatens workers in industrial and occupational processes [1]. Falling has serious, catastrophic, and even fatal complications. In some occupations, especially construction jobs, falling is the main and most important threat to workers [2,3]. Based on the nature of work in the construction industries, which are inherently dangerous, fall accidents are one of the major causes of occupational fatalities, representing 33% of all fatalities in constructions [4]. According to the Occupational Safety and Health Administration report (2019), 21.1% of workers fatalities in private industries occurred in construction, which means one in five deaths in workers was related to construction [5].

There are some situations at construction sites where we cannot eliminate risks even through a fall arrest system which prevents accidents at construction sites [6]. Difficulties in walking and balance are considered risk factors for falling [7]. Balance is a complex motor skill that involves the interaction of several complex systems, including muscular, skeletal, and nervous systems, with the environment [8]. Therefore, numerous risk factors can result in loss of balance incidents on construction sites [9]. Good individual balance ability can be essential for safe and efficient work performance; it may also improve health, modify workability, and reduce the risk of falling [10]. Studies have shown that age, height, weight, foot shape, body composition, and level of activity, and health can affect balance ability, as well as type and severity of injury [11,12].

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Nakallio reported that balance abilities have a negative correlation with age in firefighters [13]. Moein et al. reported that there were significant mild correlations between the lower leg length and body mass index with dynamic balance, and no significant relationships were found between other anthropometric features with dynamic balance in sedentary female college students [14]. Meyvaci et al. found significant effects of different foot and body parameters on functional balance performances in young male adults [15]. Lencioni et al. reported that anthropometry parameters like sex, age, body mass, and height, mainly in the frontal plane, have a significant effect on dynamic balance [16].

Body stability can be analyzed by examining dynamic and postural stability [17]. The Y Balance Test, a modified version of the Star Excursion Balance Test (SEBT), is used to assess the risk of falling in various populations and identifying any deficiency of functional movement, dynamic balance performance, and stability [18,19]. The YBT examines the distance a subject can extend the Center of Gravity (COG) over the Base of Support (BOS) to quantify boundaries of the limit of sway [20].

There is little information on the effect of individual and anthropometric characteristics on balance ability in construction workers. Therefore, this study was conducted to monitor the postural control of construction workers and investigate associations between dynamic balance abilities with demographic information and anthropometric indices.

2. Methods

2.1. Participants

This is a descriptive-analytical study conducted in 2020. One hundred and forty construction workers were asked to complete the injury history questionnaire before taking part in the study. The inclusion criteria were lack of neuromuscular and musculoskeletal diseases, including stroke, Parkinson's disease, ataxia, multiple sclerosis, symptoms of unsteadiness, dizziness or vertigo, impaired sensory function, uncorrected visual problems, ear infection, and no history of surgery on the lower limbs, and trunk in the last year. Subjects also stated that they were not taking any medication such as sedatives, hypnotics, anxiolytics, antihypertensive drugs, antipsychotics, anticholinergics, and antidepressants, and all individuals gave their personal written informed consent to participate in this study. Then 26 of them were eliminated because they did not have the required qualifications to enter the study. As a result, 114 male construction workers with normal BMI (18.5–24.9 kg/m^2) [21] participated in the study.

2.2. Demographic questionnaire and inclusion criteria

A demographic questionnaire was used to collect personal and occupational information, including age, height, weight, and work experience. The final questions of the questionnaire were related to factors related to entering the study.

2.3. Measurements of anthropometry dimensions

The anthropometry dimensions were measured using a measuring tape, anthropometer device, Marcal digital caliper, and Omron digital scale, including age, weight, height, sitting height, leg length, foot length, foot surface area (FSA = 1.043 × foot-length × ball-girth) [22], ankle width, foot breadth, heel width, ankle circumference, thigh circumference, hip breadth [23,24], and navicular drop was measured using Brody Method [25,26]. For measuring the navicular drop, participants were asked to sit in a relaxed position -hip and knee flexed at 90 degrees on a chair and place their barefoot on a firm supporting surface or on a box with 10 cm height (floor or step). The furthest protruding part of the medial navicular tubercle was marked, and then the distance from the ground to the marked navicular tubercle was measured with a plastic ruler. After that, participants were asked to stand with equal weight on both feet. The new distance was also measured. Afterward, the navicular drop was obtained by comparing measured values between the sitting and standing positions. Each measurement was conducted three times. Then, the mean was calculated.

Then, participants were classified into normal (within a range of 5 to 9 mm), flat arch (More and equal than 10 mm), and high arch (less and equal than 4 mm) foot groups based on the rate of the navicular drop [25].

2.4. Y balance test (YBT)

YBT was performed using the Y balance test kit. Participants stood with one leg on the center of the Y board, and the other leg touched down lightly just behind the plate. They reached out in the desired direction with the free leg and pushed the reach indicator

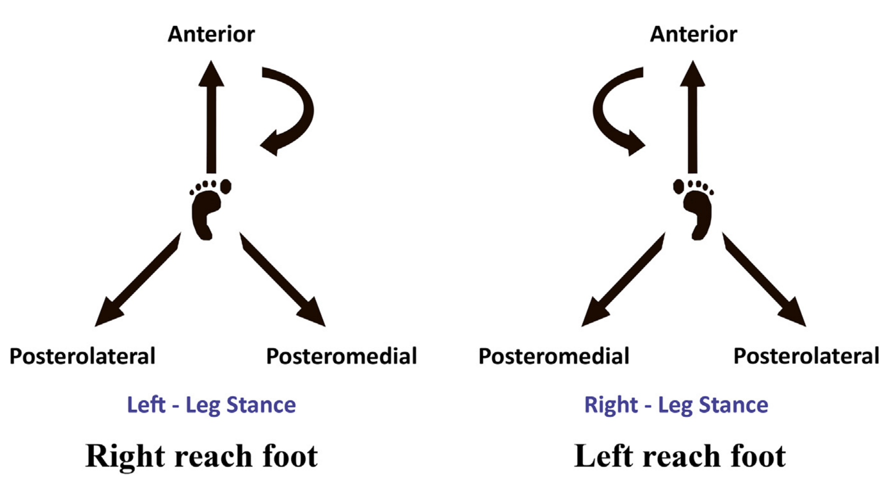

Fig. 1. Reach directions tasks for YBT [31].

Table 1
Quantitative demographic, occupational, and anthropometry information of study participants (n = 114)

Quantitative information	
Variables	Mean ± SD
Age (years)	37.79 ± 9.82
Height (cm)	176.13 ± 6.29
Weight (kg)	73.28 ± 8.09
Work experience (years)	12.85 ± 8.29
Leg length (cm)	92.11 ± 4.33
$\frac{\text{Sitting Height}}{\text{Leg Length}}$	1.01 ± 0.04
Foot Length (cm)	28.01 ± 1.83
Foot Surface (cm^2)	741.81 ± 72.72
Ankle Width (cm)	6.6 ± 0.66
Foot Width (cm)	9.58 ± 0.52
Heel Width (cm)	6.75 ± 0.68
Ankle Circumference (cm)	25.29 ± 1.96
Thigh Circumference (cm)	5.39 ± 53.84
Hip Breadth (cm)	34.10 ± 1.92
Navicular Drop (mm)	0.95 ± 0.43

SD: Standard Deviation.

as far as possible while maintaining balance. After the operation was completed in this procedure, the free foot had to be returned to the starting position. Participants were able to choose the leg to be used as the stance leg first. Three attempts were made in each anterior, posteromedial, and posterolateral direction. Participants with the right stand foot (left reach foot) performed the test in a counterclockwise direction, and those with the left stand foot (right reach foot) performed the test in a clockwise direction (Fig. 1). Participants were justified that they could not perform in following the touching down of the free leg during movement to keep balance or putting their foot on top of the reach indicator to gain support, kicking out the indicator, and crossing the starting line with their stance foot. The maximal and average reach (a distance read from the demarcated line at the proximal edge of the reach indicator) were recorded after three successful trials in each direction. Then the normalized value was calculated for both legs as composite reach and the maximal reach and average of three reach trials divided by leg length, then multiplied by 100% [18,27–30].

2.5. Statistical analysis

Descriptive statistics were used to report demographic and anthropometric information. Then the Kolmogorov-Smirnov test (K–S) was used to test normality of the data. Pearson correlation coefficient was used to investigate the relationship between dependent and independent variables. A backward stepwise multiple linear regression analysis was used to determine if anthropometric parameters could predict dynamic balance. All analyzes were performed by SPSS software version 25.

3. Results

The results showed that the mean and standard deviation of age were 37.79 ± 9.82 years. Table 1 represents the characteristics of individuals who participated in the study.

Based on the navicular drop test measurements, the medial longitudinal arch was classified into three groups in construction workers. So that 7% of the participants were in the high arch (≤4mm) category, 43.9% in the normal (5–9 mm) category, and 49.1 in the flat arch (≥10 mm) category.

The means and standard deviations of the maximal and average normalized reach of three trials in each direction of both limbs for YBT are shown in Table 2. On average, subjects showed 86.42 ± 9.28% normalized composite reach for right, and 85.93 ± 9.75% normalized composite reach for left.

Evaluation of normal distribution of dependent variable based on the Kolmogorov-Smirnov test showed that the YBT data have a normal distribution ($P \geq 0.05$).

A significant negative correlation was found between anthropometric dimensions of age, height, weight, leg length, foot length, and navicular drop with right average and maximal normalized composite reach. There was also a significant negative correlation between leg length and navicular drop with the average and maximal normalized composite reach of left the leg. Other relationships were shown in Table 3.

The Multiple Linear Regression (Backward Elimination Technique) was calculated to predict the Average Normalized Composite Reach of the Right leg ($ANCR_R$) of YBT based on demographic variables and anthropometric dimensions. The Multiple Linear Regression analyses showed that $ANCR_R$ was significantly associated with age, navicular drop, leg length, and foot surface ($F(4,109) = 9.542$, $p < 0.000$), R^2 of 0.259, and Adjusted R^2 of 0.232, which indicated that the predictor the model was able to predict 23.2% of the $ANCR_R$. B values were used for the regression equation to predict the average normalized composite reach of the right and left leg base on the reference [32] (Table 4).

Multiple Linear Regression (Backward Elimination Technique) was used to predict Average Normalized Composite Reach of left leg ($ANCR_L$) of YBT based on demographic variables and anthropometric dimensions. The Multiple Linear Regression analyses showed that $ANCR_L$ was significantly associated with age, leg length, and navicular drop ($F(3,110) = 11.325$, $p < 0.000$), R^2 of 0.236, and Adjusted R^2 of 0.215, which indicated the predictor model was able to predict for 21.5% of the $ANCR_L$ (Table 5).

Table 2
Descriptive results of YBT (n = 114)

Lower extremity	Direction	Normalized reach (%)			
		Maximal reach		Average reach of three trials	
		Mean ± SD	95% CI	Mean ± SD	95% CI
Right	Anterior (A)	94.33 ± 8.71	92.71, 95.95	92.23 ± 12.43	89.93, 94.54
	Posteromedial (PM)	84.18 ± 13.21	81.72, 86.63	83.56 ± 11.60	81.41, 85.72
	Posterolateral (PL)	83.87 ± 11.51	81.74, 86.01	82.58 ± 11.52	80.44, 84.72
	Composite	87.46 ± 9.56	85.69, 89.23	86.42 ± 9.28	84.70, 88.14
Left	Anterior (A)	93.53 ± 9.18	91.3, 95.24	92.28 ± 9.26	90.57,94.00
	Posteromedial (PM)	85.22 ± 11.67	83.05, 87.38	83.94 ± 11.81	81.74, 86.13
	Posterolateral (PL)	82.64 ± 10.89	80.62, 84.66	81.57 ± 11.05	79.52, 83.62
	Composite	87.13 ± 9.66	85.34, 88.92	85.93 ± 9.75	84.12, 87.74

Table 3
Correlations of demographic and anthropometric dimensions with YBT-based average and maximal normalized composite reach

Variables	Right				Left			
	Average normalized composite reach		Maximal normalized composite reach		Average normalized composite reach		Maximal normalized composite reach	
	r	*P*-value	r	*P*-value	r	*P*-value	r	*P*-value
Age	−0.19	0.03	−0.17	<0.01	−0.13	0.14	−0.12	0.20
Height	−0.20	0.02	−0.22	0.03	−0.15	0.09	−0.17	0.05
Weight	−0.17	0.05	−0.19	0.03	−0.12	0.10	−0.15	0.12
Leg length	−0.37	<0.01	−0.40	<0.01	−0.40	<0.01	−0.41	<0.01
$\frac{\text{Sitting Height}}{\text{Leg Length}}$	0.27	<0.01	0.27	<0.01	0.27	<0.01	0.26	<0.01
Foot Length	−0.25	<0.01	−0.22	<0.01	−0.13	0.16	−0.16	0.15
Foot Surface	0.20	0.03	0.17	0.05	0.08	0.37	0.08	0.34
Ankle Width	−0.12	0.18	−0.14	0.13	−0.07	0.42	−0.07	0.42
Foot Width	−0.10	0.24	−0.09	0.31	−0.10	0.26	−0.09	0.30
Heel Width	0.05	0.56	0.05	0.57	0.00	0.99	0.00	0.92
Ankle Circumference	0.08	0.35	0.15	0.22	0.07	0.46	0.07	0.45
Thigh Circumference	0.09	0.30	0.07	0.45	0.16	0.07	0.16	0.08
Hip Breadth	−0.13	0.14	−0.14	0.11	−0.04	0.65	−0.04	0.61
Navicular Drop	−0.25	<0.01	−0.24	<0.01	−0.24	<0.01	−0.24	<0.01

4. Discussion

The objective of this study was to investigate demographic and anthropometric predictors of the ability of dynamic balance in construction workers and to determine which anthropometric dimension has a greater role in predicting normal composite reach among construction workers.

In the YBT test, more reach in three directions indicates better equilibrium [18]. A study of dynamic balance by YBT showed that the highest average normalized reach of right and left foot is in the anterior, posteromedial, and posterolateral directions, respectively. The average combined reach distance of three directions of the right foot of construction workers is more than the left foot.

The results of this study showed that there was a statistically significant negative correlation between age and right composite reach. This means that there would be less dynamic balance in construction workers as they get older. The results also showed that about 0.238 of the composite score of the right leg and about 0.186 of the composite score of the left leg of YBT would be reduced by increasing age. In line with the present study, Nakallio [13] indicated that balance abilities in younger firefighters are better than those aged 50 and older. Robertson et al. [33] reported a significant reduction in Tandem walk eyes open capacity in participants aged 20–80 years. Norheim et al. [34] showed that dynamic balance and lower extremity function were negatively associated with age in manual workers aged 51–72 years. Regarding the effect of age on balance, it seems that older people lose balance function through loss of sensory elements, ability to integrate information and issue motor commands and lose musculoskeletal function, destroys cells in the vestibular system, affecting older ability to correct our position [35]. Also, in old age, several conditions occur at the same time, such as hearing loss, cataracts, and refractive errors, back and neck pain, and osteoarthritis [36].

As shown, there was a statistically significant negative correlation between height and right composite reach and maximal left composite reach. This means that the taller a person is, the lower the dynamic balance is. Alonso et al. pointed out that height was the most influential anthropometric variable on postural balance [11], which is consistent with the results of other studies [37,38]. They reported that shorter body height explains the better performance of balance ability. However, our observations were not compatible with those of Neji et al. [39] and Tabrizi et al. [40]. They showed that height has a significant positive correlation with dynamic balance. The observed differences may have occurred because of some differences due to the age, body compositions of the subjects, methods, and physical conditions.

In this study, there was a statistically significant difference between weight and right composite reach. This means that a decrease in dynamic balance is strongly correlated to an increase in body weight. This is in line with the result of previous studies [40–43]. These studies indicated that increased body weight affects balance function, and it can lead to poorer balance control. Bodyweight correlated with the mean speed of the center of pressure [43]. This suggests that, when submitted to daily postural stresses and perturbations, obese persons, particularly those with an abnormal distribution of body fat in the abdominal area, may be at

Table 4
Prediction of the average normalized composite reach of the right leg ($ANCR_R$) obtained from demographic information and anthropometric dimensions based on multiple linear regression test

	Sig	F	Adjusted R^2	R^2	B (unstandardized coefficient)	Beta (standardized coefficient)	t
(Constant)	0.00	—	—	—	182.70	—	10.21
Age	0.00	—	—	—	0.238-	−0.25	−3.03
Leg length	0.00	—	—	—	−0.760	−0.35	−4.17
Navicular drop	0.02	—	—	—	−0.397	−0.18	−2.25
Foot surface	0.09	—	—	—	0.018	0.14	1.69
Total	0.00	9.542	0.232	0.259	—	—	—

Table 5
Prediction of the average normalized composite reach of left leg ($NACR_L$) obtained from demographic information and anthropometric dimensions based on multiple linear regression test

	Sig	F	Adjusted R^2	R^2	B (unstandardized coefficient)	Beta (standardized coefficient)	t
(Constant)	0.00	—	—	—	180.16	—	9.95
Age	0.00	—	—	—	0.186-	−0.187	−2.22
Leg length	0.02	—	—	—	−0.903	−0.401	−4.72
Navicular drop	0.02	—	—	—	−0.422	−0.190	−2.26
Total	0.00	11.32	0.215	0.236	—	—	—

higher risk of falling than lightweight individuals because they have to generate ankle torque more rapidly and with a much higher rate of torque development to recover balance [44,45].

The results of this study indicated that there was a statistically significant negative correlation between leg length with right and left normalized composite reach. According to regression analysis, leg length explained about 0.760 normalized composite reach of the right leg and about 0.903 of normal composite reach of the left leg of YBT. That shows aone-centimeter increase in leg length predicting a drop in normalized composite reach of 0.76 and 0.903 percentage points for the right and left legs, respectively, which is consistent with the results of a study conducted by Ferreira et al. [12]; they indicated that the greater the lower limb length, the worse the directional balance control if the female group and inconsistent with the results of studies conducted by Gribble et al. [46].

Also, it pointed out that there was a significant positive correlation between the ratio of sitting height to leg length with right and left composite reach distance. This means that individuals with higher sitting height showed better performance in the dynamic balance test than those who had longer leg length.

It was obtained that there was a significant negative correlation between foot length and right composite reach. The results of current are consistent with previous findings of the study by Babayigit [47] that showed a negative correlation between dynamic balance and foot length. Ferreira et al. [12] showed that foot size had a weak effect on postural balance control in male and female groups. Birinci and Demirbas [48] reported that foot length was not associated with dynamic balance on bipedal stance. The observed differences may have occurred because of the differences in the physical conditions, methodology, the body compositions of the subjects, and individuals who did not have the same age.

As it was observed, there was a significant positive correlation between foot surface and right composite reach distance. This means that decreased foot surface resulted in a negative effect on participants' dynamic balance. It could be explained by the fact that increased foot surface area increases the base of support, thereby making the individual more stable [12,49]. Ferreira et al. indicated that females with larger foot sizes have faster reaction times and in the male group, the narrower the foot, the worse the control of balance, which maintains that the increase in the base of support size improves postural balance.

A significant negative correlation was obtained between navicular drop and composite reach distance of YBT. It was also found that about 0.397 of the composite score of the right leg and about 0.422 of the composite score of the left leg of YBT would be reduced by increasing navicular drop. This result is consistent with the results of a study conducted by Sachini et al. [50]. They reported that differences in the foot arch, especially the flat arch, could cause weakness and decline in balance ability. However, Birinci found that navicular height was not associated with dynamic and static balance [48]. Kim reported that static balance is affected in flat feet individuals but not dynamic balance [51]. These results, taken together, suggest that a flat arch of longitudinal affects dynamic balance. Our results also suggest that when construction workers have normal levels of the arch, they show better balance ability.

5. Conclusions

Fifty-six and one-tenth percent of construction workers did not have a normal medial longitudinal arch. Among the participants, the average normalized composite reach of the right leg was 86.42%, which was higher than the average normalized composite reach of the left leg. The maximal normalized reach in both legs in the anterior direction was higher than in other directions. The multiple linear regression revealed that age, navicular drop, leg length, and foot surface could predict 23% of the variance of the average normalized composite reach of the right leg, that among them, leg length plays the most important role. Age, navicular drop, and leg length with 21% are the predictor variables of average normalized composite reach of the left leg, which leg length had the greatest effect. As a result, among the predictors, leg length and the Navicular drop or medial longitudinal arch height of the foot was the anthropometric dimension that had the most effect on the average normalized composite reach in both feet, respectively.

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Conflicts of interest

The authors declare they have no conflict of interest.

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