The relationship between the exercise capacity and somatotype components, body composition, and quadriceps strength in individuals with coronary artery disease

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Abstract

Aim: The purpose of this cross-sectional study was to explore a possible relationship between exercise capacity and somatotype components, body composition, and quadriceps strength in individuals with coronary artery disease (CAD).

Material and methods: A convenient sample size of 60 participants between the ages of 45 and 60 years (mean age 56.6±4.7; 12 females [mean age 57.7±3.0], 48 males [mean age; 56.3±5.1] was established from patients referred to the Department of the Cardiopulmonary Rehabilitation. The exercise was assessed using graded symptom-limited exercise testing while Participants’ body composition was detected via Bioelectrical impedance analysis (BIA) technique by using TANITA SC-330 (TANITA, Tokyo, Japan). Finally, quadriceps femoris muscles testing was conducted with Dr. Robert W. Lovett’s manual muscle testing method.

Results: In the whole sample, exercise capacity was found to be negatively and weakly correlated with the endomorph component (r=-0.39), whereas a slight and positive correlation was observed between the ectomorph component and exercise capacity (r=0.28). However, the correlations revealed between exercise capacity and somatotype components differentiated with gender-based analysis. A moderate and weak correlation was found out between exercise capacity and fat mass (FM) in the whole group and the male individuals (r1=-0.45 and r2=-0.34), respectively; in contrast, there was not a meaningful correlation between the same variables in the female individuals (r=-0.002). Exercise capacity had slight and negative relationships with free-fat mass variable (FFM) in both gender (r1=-0.28 and r2=-0.29), while small to moderate relationship with fat-mass variable (FM) in the male gender (r1=-0.34). Body composition elements, including FM, FFM and BMI, together explained a %24 of variance in exercise capacity, while somatotype components together explained a %16 of variance in the exercise capacity. Finally, quadriceps femoris strength was found to be the best predictor of exercise capacity of a patient with CAD (R2=0.44 or % 44).

Conclusion: Our results suggest that exercise capacity in individuals with CAD is directly associated with somatotype components, anthropometry/body composition elements, and quadriceps strength.

Key words: aerobic capacity, fat mass index, body mass index, coronary artery disease, peak metabolic equivalent

Introduction

Coronary artery disease (CAD) is a significant cardiovascular disorder, which is the leading cause of death in both developed and developing countries [1]. Furthermore, because of both its most common causal factor of death in both genders and leading to diseases and social-economic burden, CAD is a significant health problem [2]. Although recently published reports have demonstrated promising decreases in the mortality rate associated with the CAD, it remains a dominant causal factor for morbidity and mortality in many communities [3]. There are many risk factors for CAD, including both modifiable risk factors such as high blood pressure, high blood cholesterol level, smoking, diabetes, overweight or obesity, lack of physical activity, unhealthy diet, stress, and conventional risk factors such as age, sex, family history, and race [4]. In other words,
biological, physiological, biochemical, environmental, and genetic risk factors are possible risk factors leading to a range of clinical phenotypes of cardiovascular diseases by interacting with one another [5]. Also, lifestyle has been found to play an essential role in developing such cardiovascular diseases [6]. The fact that the adiposity and muscularity are significantly associated with increased CAD [7] requires investigation of the possible relationship between somatotype components and coronary artery disease further. Previously, a possible relationship between somatotype components and anaerobic performance was reported in a cross-sectional study conducted by Ryan-Stewart et al. [8], indicating a significant correlation between somatotype ratings and anaerobic performance.

The relationship between physique and cardiovascular disease (CVD) has been previously investigated extensively; particularly, a possible relationship between body mass index (BMI) and coronary heart disease (CHD) has been frequently examined in cross-sectional studies [3,9,10]. A positive association was identified between morphological typology (somatotype) and muscle strength in children aged 10 to 11.5 years [11]. Ultimately, a relationship between body composition, peripheral muscle strength, and functional exercise capacity has been reported in a study by Hillman et al. [12], revealing that muscle strength and body mass might be predictive factors of functional exercise capacity. However, the body of evidence in this subject area is still insufficient and needs to be furthermore investigated. Additionally, aerobic capacity, described as a unit of metabolic equivalents (METs) or an estimate of the maximal oxygen uptake at a given workload, is one of the most common factors to predict a possible cardiovascular disease in healthy people [13,14]. As well, exercise capacity is known to be an important outcome for mortality in patients with cardiovascular disease as well as in healthy individuals [15]. Moreover, muscle strength, a significant component of physical fitness, has an essential role in preventing CAD. The existing evidence has suggested that muscle strength loss might lead to lower physical conditions and therefore reduced exercise capacity [16,17].

Despite these abundant findings, a possible relationship between exercise capacity and somatotype, body composition, and quadriceps femoris muscle strength remains to be determined. Therefore, our focus in this observational study was to explore a possible association between exercise capacity and somatotype, body composition, and quadriceps femoris in individuals with CAD.

Material and methods

Subjects

This current study was conducted in Cardiopulmonary Rehabilitation Unit of Trabzon Ahi Evren Thoracic and Cardiovascular Surgery Training and Research Hospital. The study protocol was approved by the Ethical Committee of the Faculty of Medicine of the Karadeniz Technical University for scientific research with the registration number of 24237859/187. The convenient sample size for this current cross-sectional study consisted of 60 individuals with CAD between the ages of 45 and 60 years (mean age; 56.6±4.7; 12 females [mean age; 57.7±3.01], 48 males [mean age; 56.3±5.1], who volunteered for this study. During the enrollment to the study, each patient was thoroughly informed about the study procedure, including testing procedures they would be gone through via illustrative and informative explanations. Furthermore, patients were asked to inform researchers whether they had a significant medical condition except for CAD. Also, each participant’s medical doctor was asked whether their patients had a critical medical condition preventing them from conducting testing procedures. After insightful explanations, written informed consent was obtained from all patients who accepted to participate in our study. This current study’s process complied with the provisions of the Helsinki Declaration. Inclusion criteria: diagnosed with coronary artery disease by coronary angiography, at least three months after possible revascularization surgery, no habit of regular exercise, no smoking, using the same group of drugs, and having communication skills. Exclusion criteria: uncontrolled sinu tachycardia (> 120 beats/min), congestive heart failure, acute systemic disease or fever, orthostatic hypertension, uncontrolled diabetes (blood glucose> 400 mg/dl), unstable angina, thrombophlebitis, new embolism, endocarditis, acute pericarditis, severe cardiac rhythm disturbances, severe LV dysfunction, aortic dissection, severe aortic stenosis, resting systolic blood pressure >200mmHg, resting diastolic blood pressure >110mmHg, uncontrolled atrial or ventricular arrhythmia, acute myocardial infarction (first two days) Left ventricular EF <50%, severe orthopedic impairment preventing walking and running, and balance-visual-cognitive impairment.

Measurements

A physical therapist with ten years’ experience conducted all measurements following standard procedures for each measurement under a senior medical doctor's supervision. The aim of the study was meticulously described to the patients who met inclusion criteria. Furthermore, before the assessment process, it was ensured that each participant was familiar with the testing procedures and equipment used. Finally, the reliability of the assessments was established by conducting several rehearsal assessments before the actual evaluation. There were no dropouts or adverse events throughout the study period.

Exercise capacity

The clinical exercise testing has been used to assess peak aerobic capacity to detect a potential risk of CAD for many years [18]. The evaluation of peak aerobic capacity was carried out using graded symptom-limited exercise testing, which incorporates a treadmill (GG treadmill), blood pressure module, pulse analyzer system, and an electrocardiographic monitor, according to the American heart association exercise testing guidelines [19]. All study participants were evaluated according to the Bruce ramp protocol, a valid measurement approach for maximal aerobic capacity where patients initiate exercising at 1.7 mph per hour on a 10% grade [20]. In line with the Bruce protocol, the incline and speed of the treadmill were augmented every three minutes through a total of 7 phases. General principles for conducting the exercise testing regarding contraindications and reasons for stopping tests were established according to ACC/AHA guidelines for exercise testing by Gibbons et al. [19]. In accordance with this protocol, test sessions were terminated if the subjects displayed subjective unbearable symptoms (angina, dyspnea, and fatigue), abnormalities of rhythm and blood pressure, marked and progressive ST-segment deviation, or when they were not able to maintain [21]. Metabolic equivalent (MET), blood pressure (BP), and heart rate values (HR) were obtained throughout the testing sessions. The 12 lead ECG was being monitored continuously during the exercise test.

Body composition assessment

Anthropometric measurements are a widely accepted reliable method to provide knowledge about the body's size and proportion of body fat and muscles by measuring body width, length, skinfold thickness (SF), and circumference (C)
while mesomorphic component describes a large bone mass and component is characterized by a large subcutaneous fat deposit, to the Heath-Carter classification system, the endomorphic principles was utilized to describe somatotype values. According to Heath-Carter anthropometric somatotype method for the description of the human body (somatotype), the skinfold thickness (SF), arm and calf circumferences, body mass, were used to define characteristics of the human body. However, the method evolved by the Heath and Carter is now used to categorize the human physique based on the three-level scale, including endomorph, mesomorph, and ectomorph. The somatotype components were determined based on the measurement of 16 parameters according to standard methods recommended by the International Society for the Advancement of Kinanthropometry. Data from the anthropometric evaluations, including body height, values of the diameter, bicondylar width of femur and humerus, triceps, subscapular, supraspinal suprailliac and medial calf skinfold thickness (SF), arm and calf circumferences, body mass, were used to define characteristics of the human body (somatotype), by using Heath-Carter anthropometric somatotype method for anthropometric examination. The skinfold thickness (SFs) was evaluated using the baseline skinfold caliper 12-1110. Knee and elbow widths were defined using the Holtain anthropometer set (Holstein Ltd., Crymych, Dyfed, Wales, UK). Weights were measured via Tanita body composition analyzer device (Tanita SC 330). Calf and arm circumferences were evaluated through the baseline circumference. Previous research has revealed that manual muscle testing evaluation positively correlates with isokinetic dynamometry.

Manual muscle testing for knee extension
Manual muscle testing is the most common test used as a reliable non-invasive and inexpensive method for assessing muscle strength in clinical settings. In this study, quadriceps femoris (QF) muscles testing was conducted with Dr. Robert W. Lovett’s manual muscle testing method. This test classifies muscle strength in six levels, with a higher level indicating normal power (5, normal, and 0, total paralysis). Before the actual assessment, each participant’s height was measured using the stadiometer (Denis -S200). The body mass index (BMI) was calculated by dividing weight by the square of the subjects’ height. Each participant was classified as “underweight,” “normal weight,” “overweight,” and “obese,” using the universal standard BMI equation.

Somatotype rating
The somatotype is a dominance in the human body related to the concept of body shape, the evaluation methodology of which was first developed by Sheldon to define the variations in the human body. However, the method evolved by the Heath and Carter is now used to categorize the human physique based on the three-level scale, including endomorph, mesomorph, and ectomorph. Anthropometry was carried out on the right side of each participant’s body in conformity with the previously reported guidelines. Body composition was measured via Bioelectrical impedance analysis (BIA) technique, using TANITA SC-330 (TANITA, Tokyo, Japan), a useful tool for body composition analysis in healthy adults and children. The following BIA variables were obtained: body weight, percent body fat (% BF/ FM), fat-free mass (FFM, kg). The body mass index (BMI) was evaluated through the baseline skinfold caliper. Each participant was classified as “underweight,” “normal weight,” “overweight,” and “obese,” using the universal standard BMI equation.

Table 1: Descriptive Data of Exercise Capacity, Somatotype Components, BMI, Body Fat, and Quadriceps Strength

| n=60 | Mean, SD |
|------|----------|
| Age, years (Total) | 56.3±5.1 |
| Female (n=12) | 57.7±3.01 |
| Male (n=48) | 56.3±5.1 |
| Weight (kg) | 86.3±4.4 |
| Height (cm) | 167.5±7.8 |
| MET (Min-Max) | 10.8±1.8 (7–13.5) |
| Endomorphic (Min-Max) | 6.3±1.3 (2.8–9) |
| Mesomorphic (Min-Max) | 7.2±1.4 (4.3–11.5) |
| Ectomorphic (Min-Max) | 0.5±0.7 (–1.8–2.8) |
| FFM (kg) (Min-Max) | 59.1±8.9 (36.8–79) |
| %FM (Min-Max) | 30.9±2.1 (14.8–54) |
| BMI (kg/m²) (Min-Max) | 30.7±5.1 (21.7 – 49.6) |
| Quadriceps strength (Min-Max) | 4.4±0.5 (4–5) |

Distribution of Somatotype Within Gender Group

| Gender | Endomorphic- mesomorphic | Mesomorphic- endomorphic | Total |
|--------|--------------------------|--------------------------|-------|
| Male   | 27 (56.3%)               | 21 (43.8%)               | 48    |
| Female | 3 (25.0%)                | 9 (75.0%)                | 12    |
| Total  | 30 (50.0 %)              | 30 (50.0 %)              | 60    |

Metabolic Equivalent; BMI-Body Mass Index; %FM-Percentage of Fat Mass; FFM-Free-Fat Mass
To be negatively and moderately correlated with fat mass and exercise capacity. Likewise, in the global approach, exercise capacity was found positively and slightly related to the ectomorph component. It was negatively and slightly correlated with the BMI in the whole sample (r=-0.42). Based on the gender groups, exercise capacity was negatively and slightly correlated with the BMI in the male group (r=-0.38) and moderately in the female group (r=-0.55). A statistically significant difference was found between the MET variables for different QF muscle strengths (p<0.001) (Table 3).

In the whole sample, exercise capacity was found to be negatively and weakly correlated with the endomorph and mesomorph components (r1=-0.39 and r2=-0.23). In contrast, a positive and slight correlation was observed between the exercise capacity and ectomorph component (r=0.28). However, the correlations revealed between exercise capacity and somatotype components differentiated with gender-based analysis. For example, the relationship between exercise capacity and ectomorph component was trivial in male individuals (r=0.1), whereas significant in female individuals (r=0.71). Negatively moderate and weak correlations were found between exercise capacity and FM in the whole and male individuals (r1=-0.45 and r2=-0.34), respectively; on the other hand, there was no meaningful correlation between the same variables in the female individuals (r=-0.002). As for the correlation between exercise capacity and BMI, it was revealed a negative and moderate correlation between exercise capacity and BMI in the whole sample (r=-0.42). Based on the gender groups, exercise capacity was negatively and slightly correlated with the BMI in the male group (r=-0.38) and moderately in the female group (r=-0.55). (Table 2). A statistically significant difference was found between the MET variables for different QF muscle strengths (p<0.001). In other words, the mean MET values of individuals with muscle strength of 5 was significantly higher than those with muscle strength 4 (Figure 1).

Univariate regression analysis, conducted to investigate the influence of independent variables on exercise capacity separately, demonstrated that BMI, FM, and QF strength explained % 17, % 20, and % 44 of variance in exercise capacity testing score, respectively. For the remainder of the dependent variables, it was not found out any remarkable variance explained. As for multivariate analyses, body composition elements, including FM, FFM and BMI, together explained a % 24 of variance in exercise capacity testing score, while somatotype components together explained a % 16 of variance in the exercise capacity. Finally, QF strength was found to be the best predictor of exercise capacity of patient with CAD (R2=0.44 or % 44) (Table 4).
As mentioned afore, as an atherosclerotic disease of the cardiovascular system, CAD has been reported as one of the most causal factors of morbidity and mortality in both developed and developing countries [32]. Also, CAD has been demonstrated to be one of the essential factors of the disability [33]. Although advanced preventative and therapeutic approaches have significantly decreased the severity of the prognostic of cardiovascular diseases over the last decades [32]; however, CAD and related cardiovascular system diseases remain a vital risk of death in the global population. Physical bodily characteristics or body habits, including fat-free mass, total body fat, subcutaneous fat pattern, somatotype (body shape), and relative weight and height (BMI measurements), have been reported as potential risk factors of cardiovascular diseases [3, 9]. Importantly, exercise or peak aerobic capacity was demonstrated to be a substantial prognostic factor in patients with or at risk of cardiovascular diseases [15, 34].

To date, many research focused on potential associations between somatotype components and cardiovascular diseases [3, 7, 35]. Furthermore, a previous study by Malina et al.[36] investigated possible relationships between somatotype components and cardiovascular risk factors in healthy adults, showing low to moderate relationships between these variables. As a result, considering that somatotype components are the important predictors of CAD [37], the varying degree of relationships between exercise capacity and somatotype components reported in this current study were not surprising. Marta et al.’s study [38] demonstrated that the prevalence of coronary heart diseases in males was three times higher for endomorphic-mesomorphs than dominant ectomorphs. Similar to this result, we found that CAD was less relevant to ectomorph component than to endomorphic-mesomorphic dyads. These additional results of our study confirmed that individuals characterized by ectomorphic dominance would be at a lower risk of coronary heart disease or CAD than their endomorphic-mesomorphic peers. In other words, in this current study, the aerobic capacity of participants qualified with the ectomorphic component was found to be greater than those with endomorphic-mesomorphic body habits. Another study [39] suggesting that the dominant somatotype affects exercise capacity and explosive strength in prepubescent children is closely related to our research results. The findings of a study demonstrating that the endomorphic component negatively affects exercise capacity [40] are in line with these results of our study. In conclusion, considering that exercise capacity is a strong prognostic factor for cardiovascular diseases and mortality [15, 41, 42], it is vital to identify factors that negatively affect exercise capacity to improve or change them.

The modestly and inverse relationship between body fat percentage and exercise capacity in the current study can be attributed to the fact that a higher than normal body fat ratio may contribute less to energy production [43, 44]. As well, the relationship between body fat and endomorph physique [39] confirm this meaningful relationship. As a result, the present results add to the evidence that increased fat mass is intimately related to with decreased exercise capacity [39, 45]. Gorant et al.[46] suggested that body fat did not influence VO2max or peak exercise capacity. However, our study results on the relationship between body fat and exercise capacity contradicted these study results. Surprisingly, this meaningful relationship between exercise capacity and body fat ratio in the general population differed by gender factor: While our study's findings show that body fat percentage negatively affects exercise capacity in men individuals, no such effect was found in women. This surprising result can be attributed to the small number of women in our study. Many researchers have reported that high BMI and increased body fat percentage in different populations adversely affect exercise capacity and physical fitness [47, 48]. Thus, a similar relationship exists in individuals with coronary artery disease, reinforcing that high BMI and increased body fat percentage predispose them to cardiovascular diseases. In this current study, it was found that knee extensor muscle strength was positively correlated with aerobic capacity. High lower extremity muscle strength paves the way for better exercise capacity; it results in less development of cardiovascular disease and consequently a lower risk of death. While the research on this subject mostly includes studies conducted on healthy individuals [49, 50], studies on individuals with coronary artery disease are extremely limited. Therefore, our study results reveal the relation between knee extensor muscle strength and right side in individuals with coronary artery disease to the limited literature. As a result, physical activity habits that increase physical fitness, as previously reported [24], are highly likely to reduce the risk of sudden cardiac death and acute myocardial infarction. It is critical in reducing coronary artery disease risk by keeping physical fitness parameters at an optimal level [51]. Also, a meta-analysis study conducted on this subject reported that Exercise-based cardiac rehabilitation reduced morbidity and mortality by 20-25% [52].

Study limitations

Despite its novel findings, our study may have several limitations. First, almost all the relationships between exercise capacity and dependent variables differentiated with gender-based statistical analysis. This may have very likely arisen from the small number of female patients. Later, all study participants were randomly recruited from the patients referred to the Cardiopulmonary Rehabilitation Unit of Trabzon Ahi Evren Thoracic and Cardiovascular Surgery Training and Research Hospital. Thus, further research is needed to investigate this subject in a broader population with CAD.

Conclusion

The current study was the first to explore the relationship between exercise capacity and body composition, somatotype components, and QF muscle strength in patients with CAD. Exercise capacity was found out to be negatively related to the endomorphic and mesomorphic components, suggesting that endomorphic-mesomorphs physique may negatively influence patients’ aerobic capacity with CAD. In contrast, exercise capacity was revealed to be positively associated with the ectomorphic physique, demonstrating that little fat mass may positively affect the exercise capacity. Likewise, in patients with CAD, exercise capacity was negatively and modestly associated with body fat mass and BMI, showing that lower body weight and adiposity in patients with CAD is essential. On the other hand, there was no meaningful relationship between exercise capacity and lean body mass. Finally, a significant and positive relationship between QF muscle strength and exercise capacity was revealed. In other words, quadriceps femoris strength might be a predictor of exercise capacity in patient CAD. Consequently, we suggested that somatotype components, adiposity, body composition, and QF muscle strength are meaningfully related to exercise capacity in the population with CAD.
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Consent to participate: Informed consent was obtained and signed by all patients.

Consent for publication: All the authors consent for publications.

Data sharing and data availability: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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