The Relationship Between CPAT, Strength, Endurance, and Body Composition for Female Firefighters

by

Hampton Elyse Brinson

A thesis submitted to the Graduate Faculty of
Auburn University at Montgomery
in partial fulfillment of the
requirements for the Degree of
Master of Science

Montgomery, Alabama
May 9, 2020

Keywords: push-ups, pull-ups,
Vo2 max, anaerobic power, body composition

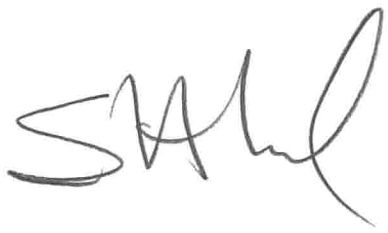
Approved by

Henry Williford Jr., Chair, Professor of Kinesiology

Angela Russell, Assistant Professor of Kinesiology

Shawn Mitchell, Assistant Professor of Kinesiology

Deanne Allegro, Assistant Professor of Kinesiology



The Relationship Between CPAT, Strength, Endurance,

and Body Composition for Female Firefighters

by

Hampton Elyse Brinson

A thesis submitted to the Graduate Faculty of
Auburn University at Montgomery
in partial fulfillment of the
requirements for the Degree of
Master of Science

Montgomery, Alabama
May 9, 2020

Keywords: push-ups, pull-ups,
Vo2 max, anaerobic power, body composition

Approved by

Henry Williford Jr., Chair, Professor of Kinesiology_____

Angela Russell, Assistant Professor of Kinesiology _____

Shawn Mitchell, Assistant Professor of Kinesiology_____

Deanne Allegro, Assistant Professor of Kinesiology_____

Table of Contents

LIST OF TABLES AND FIGURES (pg 20)

ABSTRACT

The CPAT is an entry-level firefighter test that both men and women must pass prior to becoming a firefighter. Event one of the CPAT is the stair climb (also known as step mill test) which is physically demanding, and is also one of the reasons why there is a low percentage passage rate related to potential women firefighters. This study evaluated the different fitness demands required for women planning to pursue a career as a firefighter. Thirty women volunteered to take part in the study, age 25.7 ± 3.9 years, height 165.2 ± 5.7 cm, weight 64.7 ± 13.3 kg. The women were evaluated on the following variables: push-ups, pull-ups, cardiovascular fitness, anaerobic power, and body composition. Cardiovascular fitness ($VO_{2max)}$ ml•kg^{-1}•min^{-1})) was measured by indirect calorimetry, anaerobic power (W) by the Wingate anaerobic power test, and body composition by BODPOD. The following are the mean ± SD values for each of the variables: push-ups 20.5 ± 10.4, pull-ups 1.6 ± 2.3, Vo_{2max} 37.1 ± 8.6, Wingate anaerobic power test 421.2 ± 122.4 W, body fat percent 26.1 ± 8.4 %, lean body mass 47.1 ± 7.3 kg, and the StairMaster time 1.7 ±0.8 min. Pearson Correlations were calculated between each of the independent variables and the stair climb: push-ups (r=.302, p=.104), pull-ups (r=.481, p=.040), Vo_{2max} (r=.601, p=.000), peak anaerobic power (r=.210, p=.266), body fat percent(r=-.697, p=.000), mean anaerobic power (r=.392, p=.032)and lean body mass (r=.433, p=.017). Significant correlations ($p<0.01$) were found between CPAT stair climb and the following: body fat, lean body mass, mean power, and $Vo_{2max.}$ Findings from the present study show the relationship between body composition and fitness related variables in relationship to performance on the step mill test. Potential women firefighter recruits can use this information in their preparation for the CPAT test.

Keywords: push-ups, pull-ups, Vo2 max, anaerobic power, body composition

INTRODUCTION

The physical demands of firefighting are characterized by the activation of cardiovascular, muscular, metabolic, and endocrine systems (15). Firefighting is not only a strenuous and dangerous occupation; it also demands a highly fit athlete that must be able to perform at optimal levels under extreme conditions. Firefighters respond to a dynamic set of environmental conditions for extended periods of time (11, 16). According to the *National Fire Protection Association,* out of 300,000 total firefighters, women make up only 7% of the population (20). Why is there such a shortage of women in firefighting? With an industry filled with over 93% men, one potential reason may be related to potential recruits passing the Candidate Physical Activity Test (CPAT) (30). The current study evaluated what variables are related to completing the step mill portion of the CPAT.

The CPAT was developed in 1997 by the International Association of FireFighters (14). The CPAT requires firefighters to be physically capable of meeting the job requirements needed by a firefighter (7). The test challenges both aerobic and anaerobic energy systems of potential candidates. While there is no statistical data to show what percentage of female firefighters pass the CPAT entry level test, there are a number of women who are not physically able to complete the step mill portion of the test.

The CPAT requires a participant to complete 8 events while wearing a 22.68 kg vest. In the first event, which is the stair climb, the participant must climb stairs wearing the vest while an additional 11.34 kg in weight is added to the person to simulate a hose pack. There are physiological differences between men and women regarding physical

fitness and performance, however the job requirements of a firefighter are the same. The CPAT does not discriminate between men and women. The CPAT is often a barrier for potential women recruits due to the lower passage rate on the stair climb. Therefore, the purpose of this study was to investigate the relationships between the stair climb, strength, endurance, power, and body composition in potential women firefighters.

METHODS

Subjects

Thirty women (N=30) (age 25.7 ± 3.9 years, height 165.2 ± 5.7 cm, weight 64.7 ± 13.3 kg) were recruited to participate in the study from the university and fitness center in the surrounding geographic area. Subjects were screened for signs or symptoms of cardiovascular or pulmonary disease as determined by a physical activity readiness questionnaire (Par-Q). Participants filled out a health history questionnaire and an informed consent form before starting the study in order to verify health risks as defined by the American College of Sports Medicine (ACSM) risk stratification guidelines for exercise testing (1). The women were given an explanation of the study and the study was approved by the Institutional Review Board prior to initiating the study.

Procedures

All participants were tested in the Human Performance Lab at Auburn University at Montgomery in Montgomery, AL. Data was collected and analyzed over three non-consecutive visits with at least 48 hours between testing sessions. On the first visit, participants had their height measured using a wall mounted stadiometer (SECA; Seca Instruments Ltd, Hamburg, Germany), weight was measured using a calibrated digital

scale (Tanita BWB-800-A, Tanita Corp, Tokyo, Japan). Body fat percentage and lean body mass were assessed using a BOD POD Gold Standard Body Composition Tracking System (COSMED The Metabolic Company, Rome, Italy). Subject's height was measured in centimeters to the nearest tenth with their shoes off, back against the wall, and hands by their sides.

The first fitness test item was push-ups. Participants performed a maximum repetition push-up test (1). Push-ups were performed starting in the down position with hands pointing forward, back straight, head up, and elbows at a 90-degree angle. Participants were told if their arms did not come to a full 90-degree angle or their stomach dropped to the floor, then the test was complete. The maximum number of push-ups completed without rest was counted as the score.

The next test was a maximal graded exercise test (GXT), which was performed using a metabolic cart (ParvoMedics TrueOne 2400 metabolic cart, Sandy, UT, USA) on a treadmill to determine the subject's maximal oxygen consumption (Vo_{2max} in $ml \bullet kg^{-1} \bullet min^{-1}$). The Bruce Protocol, was followed and the treadmill speed and grade increased every three minutes (1). Participants wore a Polar Heart Rate Monitor (Kempele, Finland) to record heart rate every three minutes before going into the next stage. Maximal effort was determined by a RER > 1.15, a RPE greater than 8 (on a 10 point scale) and a HR max ± 10 of max predicted HR. Posttest, a cool down period took place for 3-5 minutes in order for heart rate to decrease within 20 beats of the initial resting heart rate.

During visit 2, subjects completed a maximum pull-up test (1). Subjects started in a down position with arms fully extended. For the pull-up to count, the participant's chin

had to come above the bar and arms had to come back down to a fully extended position. If subjects dropped from the bar or stopped from fatigue the test was stopped and the number of completed pull-ups was recorded as the max.

Anaerobic power was performed by The Wingate anaerobic test (4). Participants warmed up for 3-5 minutes on the Velotron mechanically braked cycle ergometer (Velotron, Varberg, Sweden). The resistance was set at 5% of body weight. Anaerobic power was the peak value computed during the 30-second test, and average power was the power averaged during 5-second increments. Once the test was complete, subjects continued to pedal for an active cool down period of 2-3 minutes without resistance on the flywheel.

On the final day of testing, participants performed the CPAT stair climb, which replicates the actual firefighter stair climb test. The purpose of the test was to evaluate the critical task of climbing stairs in full protective gear and clothing while carrying a high-rise pack. The event requires cardiovascular fitness, muscular strength and endurance, and balance. During this test, subjects wore long pants, a hard hat with a strap, work gloves, and shoes with no open heel or toe. The event required the subjects to wear a 22.68 kg weighted vest plus two 5.67 kg weights on their shoulders to simulate the weight of a high-rise pack and turn out gear. Prior to starting the 3 minute timed test, participants performed a 20 second warm up on the StairMaster at a stepping rate of 50 steps per minute. During the warm-up, subjects were able to grasp the rail or wall to regain balance and cadence. If they dismounted during the warm-up they had to restart the 20-second warm-up period. They were allowed to restart the period twice. The test began immediately after the successful completion of the warm-up, with no rest period

between the two. For the test, subjects walked on the StairMaster at a stepping rate of 60 steps per minute for 3 consecutive minutes. For this study, subjects stepped as long as possible up to the 3-minute period required to pass the CPAT test. The timer recorded the length of time subjects were able to perform the test. Participants were allowed two warnings during the testing procedure before the test was stopped and time was recorded.

Statistical Analysis

SPSS was used for statistical analysis (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) The descriptive statistics consisted of means and standard deviations (SD±). Pearson correlations (r) were performed between CPAT times and each of the independent variables. The Alpha level was established at $p < .05$.

Results

Table 1 shows the mean ± SD values of the descriptive statistics for the 30 women. Table 2 shows the mean ± SD values and METs for the performance variables. Table 3 reports the correlation coefficients between CPAT time and the evaluated fitness and body composition variables. Results found that percent body fat (BF%) was significantly negatively related to step mill performance (r=-.697, p=.001) while LBM was positively related (r=.433, p=.017). Push-Ups (r=0.302, p=.104) were not significantly related, while pull-ups were significant (r=.481, p= .040). Wingate peak power (Watts) was not significant (r=.210, p=.266), while average power was significant (r=.392, p=.032).

Of the 30 women who performed the step mill test, only seven were able to complete the 3-minute test. Because of the low passage rate, the statistical analysis

evaluated the relationships between the independent variables and how long the participants were able to perform the test up to 3 minutes. The 24% passage rate in this study is similar to what the researchers have observed in a number of fire departments they consult with who are recruiting women firefighters.

Discussion

Firefighting is a strenuous occupation that requires a high level of fitness related to both health and performance (17). Fatal and non-fatal injuries occur while fighting fires and during training. The CPAT test is an entry-level test that is traditionally performed prior to being employed as a firefighter and participating in training. The number of women employed as firefighters is extremely low as compared to men. The Montgomery Fire and Rescue Department, Montgomery, Al has approximately 5 women firefighters compared to over 400 men. According to the National Report Card on Women, of the 300,000 firefighters in the U.S., only 7% are women (13). Of the 291 fire departments in the U.S. that are considered metropolitan, more than half have no women in the department. According to Jahnke et al. a target goal has been established that 16 to 22% of firefighter personnel should be women (16).

Initiatives have been developed to employ more women firefighters; however, there are not a large number of applicants and the passage rate to the CPAT is low. Jahnke et al. reported there is no data to suggest the proportion of women in the fire service is increasing due to a combination of limited recruitment and poor retention (16). The first part of the CPAT is the stair climb test, which must be completed prior to attempting the other portions of the CPAT. The 3-minute timed step mill with the weighted vest and additional weight added has been shown to be difficult for women to

complete. However, there are women who pass the test on the first attempt and others who have failed the test but have trained and passed on further attempts.

The present investigation evaluated the relationship between body composition and step mill time. The results show LBM was significantly related to performance time. When climbing stairs with a weighted vest and additional weight added to the torso, LBM is an important variable in predicting performance of this task. There are a number of investigations, in both men and women, that report that body fat can be detrimental to both firefighter health and job performance, while LBM is significantly positively related to performing work while carrying additional loads. Excess high body fat values add additional weight and stress to a firefighter, plus the added weight of firefighting gear (PPE), makes physical tasks much more demanding which decreases power output and increases work time (27, 5). The majority of research in this area is with men, however Kirlin et al. conducted a cross-sectional study of women firefighters (ages 22-60 yrs) and found women firefighters tend to have mean body fat values of 22-27%, which is considered a health body fat value for women (17). Body fat correlations (r=-.697) and LBM (r=.433) were found to be related to both cardiovascular fitness and muscular strength and endurance. Misner et al. also evaluated body composition in 25 women firefighters and fat was found to have a negative influence on firefighter physical tasks while fat-free weight had a positive influence on firefighter performance tasks requiring application of force such as lifting, carrying, and striking activities (21).

Findley et al. reported that power is an important variable related to firefighter performance (9). Specifically, climbing stairs, laying hose, structure ventilation, and rescue operations require both muscular strength and power. Misner et al. evaluated the

anaerobic power of a large group of female firefighters. They analyzed the relationship of body composition, leg power, and leg strength tests to performance on the Wingate Anaerobic Test (W). A secondary purpose was to observe the relationship of the Wingate to a stair-climbing test used to select firefighters. They found mean power (MP), peak power (PP), and percent fatigue (%F) were significantly related to the stair climb. In addition, LBM accounted for the most variation in power output (20). Sheaff et al. also found mean power during the Wingate test was significantly related to step mill performance time (29). The present investigation found a significant relationship between mean power and the stair climb (r=.392). The mean power output was 269.74 ± 62.16 watts. The individuals who were able to complete the 3-minute stair climb had a slightly higher mean power output of 286.40 ± 97.79 watts. Overall peak power was not significantly related to performance; however, mean power was significant. One possible explanation for mean power being a better predictor than peak power is the fact that the step mill test is a 3-minute test and requires a high-power output over time.

Table 2 shows the results of the push-up and pull-up tests. Push-ups were not significantly related to performance time; however, pull-ups were. Other investigations evaluating overall firefighter fitness and job performance have reported push-ups were significantly related to firefighter job performance (19, 30). According to push-up norms for women, the current sample performed only in the fair category for push-ups with a mean of 20.50. The SD was 10.49 which indicates high variability for this sample. The mean number of pull-ups was 1.66 ± 2.32. A number of women could not do a pull-up. One interesting finding was that all of the women who completed the 3-minute step mill test were able to perform 2 or more pull-ups.

Furthermore, the NFPA and other researchers have recommended that firefighters possess a cardiovascular fitness level of 12 METs in order to meet performance standards associated with firefighting (11). The mean value of the current sample was 10.6 METs, which was less than the professional 12 MET standard. The mean VO_{2max} ($ml \bullet kg^{-1} \bullet min^{-1}$) was 37.10 ± 8.67, and values ranged from 36.5 to 52.7 $ml \bullet kg^{-1} \bullet min^{-1}$ for individuals who were able to complete the 3 minutes on the step mill. VO_{2max} was significantly correlated to step mill time, r=.601, p=.001. In a cross-sectional study evaluating 96 women firefighters ranging in age from 25 to 60 years, Kirlin et al. concluded that cardiovascular fitness was one of the most important variables related to firefighter performance, and should be maintained throughout a firefighter's career. The mean VO_{2max} values for their age groups were all greater than the NFPA 12 MET standard, and were comparable to mean values reported in men firefighters (17). Sheaff et al. assessed 33 firefighters and found absolute maximal oxygen uptake was significantly higher in those who passed the step mill than those who did not (29). It is well documented that cardiovascular disease is the leading cause of death in on-duty firefighters (18). The majority of research in this area is with male firefighters; however, it has been reported that 5% female firefighters have metabolic syndrome, which is related to low cardiovascular fitness. Cardiovascular fitness is not only related to the step mill test but overall job performance in firefighters (31).

Conclusion

Findings from the present study show the relationships between body composition and fitness related variables in being able to perform the CPAT step mill test. There is little research with women firefighters and the barriers that preclude them from passing

the entry-level test. Body composition is a very important predictor of passing the test as lean body mass is highly related to performance when performing tasks where additional weight is added to the body. The inverse relationships between body fat and the length of time the individual can perform the test is also important. Firefighting is a demanding job from a physical performance standpoint. Cardiovascular fitness, muscular strength, and mean power were all significantly related to performance times on the step mill. Each of these variables have also been shown to be significantly correlated to overall firefighter job performance.

Practical Application

There is a scarcity of research data with women firefighters as compared to men. Fire departments are attempting to recruit more women firefighters; however, the women must meet the entry-level standards. The physical demands of the CPAT demand appropriate levels of fitness. This is an opportunity for the strength and conditioning coaches to be involved in providing the training necessary to meet the demands of women firefighter potential recruits. Firefighters have often been classified as athletes and have similar needs in regards to training and conditioning. This is an excellent population to work with in providing a needed service to fire departments who are attempting to recruit more women firefighters.

References

(1) American College of Sports Medicine. *Guidelines for Exercise Testing and Prescription 9th Edition*. Baltimore, MD: Lippincott, Williams & Wilikins, 2014.

(2) Attia A, Hachana Y, Chaabène H, Gaddour A, Neji Z, Shephard RJ, and Chelly MS. Reliability and Validity of a 20-s Alternative to the Wingate Anaerobic Test in Team Sport Male Athletes. *PLoS ONE 9*, 2014.

(3) Auferoth S. Conditioning new recruits: The physical readiness program. *Fire Engineering 162*: 65, 2009.

(4) Bringhurst RF, Wagner DR, and Schwartz S. Wingate Anaerobic Test Reliability on the Velotron with Ice Hockey Players. *J Strength Cond Res*, 2018.

(5) Davis PO and Starck AR. Excess body fat-not age viewed as a greater culprit in fitness decline. *Fire Engineering* 13: 33-37, 1980.

(6) `Del Sal M, Barbierl E, Garbati P, Sisti D, Rocchi M, and Stocchi V. Physiologic Response of Firefighter Recruits During a Supervised Live-Fire Work Performance Test. *J Strength Cond Res*, 2009.

(7) Dennison KJ, Mullineaux DR, Yates JW, and Abel MG. The effect of fatigue and training status on firefighter performance. *J Strength Cond Res* 26: 1101-1109, 2012.

(8) Elsner K, and Kolkhorst F. Metabolic demands of simulated firefighting tasks. *Ergonomics* 51: 1418-1425, 2008.

(9) Findley BW, Brown LE, and Whitehurst M. Anaerobic Power Performance of Incumbent Female Firefighters. *J Strength Cond Res* 16: 474-476, 2002.

(10) Gendron P, Freiberger E, Laurencelle L, Trudeau F, and Lajoie C. Greater physical fitness is associated with better air ventilation efficiency in firefighters. *Appl Ergon* 47: 229-235, 2015.

(11) Gledhill, JN. Characterization of the Physical Demands of Firefighting. *Canadian J Sport Sciences* 17: 207-213, 1992.

(12) Heyward V. ASEP: Methods Recommendation: Body Composition Assessment. *J Exerc Physiol* 4, 2001.

(13) Horn G, Gutzmer S, Fahs C, Petruzzello S, Goldstein E, Fahey G, and Fernhall B. Physiological recovery from firefighting activities in rehabilitation and beyond. *Focus on Firefighter Physiol* 15: 214-225, 2010.

(14) Hulett DM, Bendick M, Thomas SY, and Moccio F. A National Report Card on Women in Firefighting. Madison, WI: *International Association of Women in Fire & Emergency Services,* 2008.

(15) International Association of Firefighters. *The Fire Service Joint Labor Management Wellness-Fitness Initiative 3rd Edition*. Washington, DC: International Association of Firefighters, 2008.

(16) Jahnke SA, Poston WC, Haddock CK, Jinarin N, Hyder ML, and Horvath C. The heath of women in the US fire service. *BMC Women's Health* 12: 39, 2012.

(17) Kirlin LK, Nicholas JF, Rusk K, Parker RA, and Raulh MJ. The effect of age on fitness among female firefighters. *Occup Med* 67: 528-533, 2017.

(18) Li K, Lispey T, Leach HJ, and Nelson TL. Cardiac health and fitness of Colorado male/female firefighters. *Occup Med (London)* 67: 268-273, 2017.

(19) Lindberg A, Oksa J, Gavhed D, and Malm C. Field Tests for Evaluating the Aerobic Work Capacity of Firefighters. *PLoS* 8, 2013.

(20) Michaelides MA, Parpa KM, Henry L, Thompson GB, and Brown BS. Assessment of physical fitness aspects and their relationship to firefighters' job abilities. *J Strength Cond Res*. 25: 956-965, 2011.

(21) Misner JE, Boileau RA, Plowman SA, Elmore BG, Gates MA, Gilbert JA, and Horswill C. Leg Power Characteristics of Female Firefighter Applicants. *J Occup Ther* 30: 433-437, 1998.

(22) Misner JE, Boileau RA, Plowman SA, Elmore BG, Gates MA, Gilbert JA, and Horswill C. Physical Performance and Physical Fitness of a Select Group of Female Firefighter Applicants. *J Appl Sport Sciences Res* 3: 62-67, 1989.

(23) Muegge CM, Zollinger TW, Saywell RM, Moffatt SM, Hanify T, and Dezelan LA. CPAT: Putting the Test to the Test. *Fire Engineering* 155, 2002.

(24) National Fire Protection Association. *NFPA 1582: Standard on Comprehensive Occupational Medical Program for All Fire Departments*. Quincy, MA: NFPA, 2013; 98.

(25) Oksa J, Rintamaki H, Takatalo K, Makinen T, Lusa S, Lindholm H, and Rissanen S. Firefighters muscular recovery after a heavy work bout in the heat. *Appl Physiol, Nutrit Metab* 38: 292-299, 2012.

(26) Rhea MR, Alvar BA, and Gray R. Physical Fitness and Job Performance of Firefighters. *J Strength Cond Res* 18: 348-352, 2004.

(27) Rhyan S. Improving Fatigue Resistance for a Firefighter Physical Ability Test. *Strength Cond J* 28: 60-67, 2006.

(28) Sal MD, Barbieri E, Garbati P, Sisti D, Rocchi MB, and Stocchi V. Physiologic Responses of Firefighter Recruits During a Supervised Live-Fire Work Performance Test. *J Strength Cond Res* 23: 2396-2404, 2009.

(29) Sheaff AK, Bennett A, Hanson ED, Kim YS, Hsu J, Shim JK, Edwards, ST, Hurley, BF. *J Strength Cond Res* 24: 3112-3122, 2010.

(30) Williams-Bell FM, Villar R, Sharratt MT, and Hughson RL. Physiological Demands of the Firefighter Candidate Physical Ability Test. *Med Sci in Sports & Exerc 41*: 653-662, 2009.

(31) Williford H, Duey W, Olson M, Howard R, and Wang N. Relationship between fire fighting suppression tasks and physical fitness. *Ergonomics* 42: 1179-1186, 1999.

(32) Young Lee J, Bakri I, Kim J, Son S, and Tochihara Y. The Impact of Firefighter Personal Protective Equipment and Treadmill Protocol on Maximal Oxygen Uptake. *J Occup Environ Hyg* 10: 397-407, 2013.

Figure, Tables, and Graphs

Table 1. Descriptive Statistics of Women Firefighters

	N	Mean	Std. Deviation
Age (yrs)	30	25.70	3.94
Height (in)	30	65.73	1.98
Body Fat %	30	26.15	8.40
Lean Body Mass (kg)	30	47.14	7.33
Weight (kg)	30	64.70	13.35

Table 2. Descriptive Statistics of Performance Variables

	N	Mean	Std. Deviation	Mean METs	Std. Deviation METs
Vo_{2max} ($ml \bullet kg^{-1} \bullet min^{-1}$)	30	37.10	8.67	10.60	2.47
Pull-ups	30	1.66	2.32	0.47	0.66
Push-ups	30	20.50	10.49	5.85	2.99
Heart Rate Max	30	183.03	11.66	52.29	3.33
Peak Power (W)	30	421.21	122.42	120.34	34.97
Average Power (W)	30	269.74	62.16	77.06	17.76

Table 3. Correlation Matrix Between Step Mill CPAT Time, Body Composition and Performance Variables

	Body Fat %	Vo2 Max	Push-Ups	Pull-Ups	Peak Power	Mean Power	Lean Body Mass	Weight (kg)	CPAT Time
r=	-.697	.601	.302	.481	.210	.392	.433	-.082	1.00
p=	0.01	0.01	.104	.040	.266	.032	.017	.666	0.00