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Effect of Increased Daily Food Intake and Resistance Training on Body Composition, Body Dimension, Strength and Metabolic Variables among Underweight Males

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ABSTRACT

The aim of this study was to treat underweight by combining training and diet. 47 underweight college males were divided into, a Combined Resistance Increased Food Intake Group-1 (CRIFIG-1), a Combined Resistance Normal Food Intake Group-2 (CRNFIG-2), an Increased Food Intake Group-3 (IFIG-3), and a Normal Food Intake Group-4 (NFIG-4). The resistance training (RT) was for 30 min/session twice a week, for 8 weeks. Mean, standard deviation, Paired t-test, ANOVA and repeated measures were used to analyze data. The significance level was 0.05. CRIFIG-1 and CRNFIG-2 reported significant increases in all Resistance Measures (RM) ($P < 0.05$). The Total Daily Energy Requirement (TDER) displayed higher values than the Total Daily Food Intake (TDFI) in all groups ($P \leq 0.001$). It was concluded that the RT had significant effects on the training groups in all RM (paired t-test); however, all underweight subjects showed an energy deficiency at the end.

Keywords: *Energy Requirment, Energy Expenditure, Food Intake, Resistance Training, Underweight*

INTRODUCTION

Underweight is a health problem, associated with several medical risk factors such as hyperthyroidism [1], diet deficiency, and genetic. They have low appetite for consuming food and small stomachs which makes them lean. The insufficient energy intake of underweight may lead to the utilization of stored fat and lean tissue as energy, resulting in the decrease of strength, the endurance, the endocrine and the musculoskeletal functions [2]. Thus, the underweight person can be treated by resistance training (RT) and increasing total daily food intake (TDFI).

Several studies compared the total daily energy expenditure (TDEE) and the TDFI among normal weight elite male runners [3, 4], elite females [5, 6], male athletes [7, 8], female soccer players [9] and mixed gender athletes [10, 11]. One study used elite underweight Kenyan male runners [3]. Many investigations reported that the TDEE exceeded significantly the TDFI [3;7,11] by -1583, -346, -618, -1743, -6096 and -496 kcal/day, respectively. However, few studies noted no changes [9,10]. The RT strengthens and conditions the musculoskeletal system [12], improves muscle tone [13], muscle size [14], tendon, ligament strength, bone mineral density [15], and endurance [16]. It also enhances the psychological health by expanding self-esteem [17], confidence, and self-worth. In addition, RT leads to better sleep pattern, [18], economy of movement [19], optimizes recovery [20], improve fitness [21], prevent osteoporosis [22] and finally develop jump and speed [23]. Several studies in 1RM LP [24; 28] noted increases by 66, 27, 18, 26 and 62%, respectively, after RT. An enlargement of 27, 53, 30 and 16% were observed in 1RM LE [24,26,29,30]. In 1RM CP, significant raises were stated by 32% [31], 39% [7], 19% [32], 12% [33], 14% [26] and

20% [28]. In 1RM PD an extension of 6% was confirmed [26]. In BM, gains of 7% [27] and 1% [33] were declared for underweight subjects; however, similar outcome was indicated in untrained men [24]. FFM enlarged by 2, 1 and 3% [27,33,34] respectively. TBW showed remarkable growth by 9% [33]. To our knowledge, no study was carried out to treat the underweight subjects using combined RT with increased TDFI. Further, no study calculated the TDER before the start of training and asking the subject to increase his TDFI, then comparing the actual TDFI with the TDER. Therefore, the objective of this research was to compare the impact of combined increased TDFI with RT on BC, BD, MM and RM among underweight males. It was hypothesized that the CRIFIG-1 would take over CRNFIG-2 and NFIG-4 in MM and IFIG-3 and NFIG-4 in RM. CRNFIG-2 also would lead over IFIG-3 and NFIG-4 in RM.

MATERIALS & METHODS

To address the study problem, the investigators depended on two factors, namely RT and increased TDFI. The RT was performed 8 weeks, twice a week for 30 min per session combined with an increase TDFI. The TDER and the TDFI of all subjects were calculated before the start of training. The actual TDFI was compared with the actual TDER. The actual TDER was found more than the actual TDFI, the subjects were asked to increase their TDFI to equalize their TDER or more.

Subjects

The Ethics Committee of KFUPM gave its approval for this study to collect data on human subjects. A written consent was taken from all subjects and they were free to withdraw in case they felt any discomfort during the study. Forty seven, underweight sedentary males from King Fahd University of Petroleum & Minerals aged 18 to 22 years participated in this study. The selection of subjects depended on the body mass index of less than 18.5 kg/m^2. The participants were catogerized into four groups, a Combined Resistance Increased Food Intake Group-1 (CRIFIG-1, n = 16), a Combined Resistance Normal Food Intake Group-2 (CRNFIG-2, n = 14) an Increased Food Intake Group-3 (IFIG-3, n = 9), and a Normal Food Intake Group-4 (NFIG-4, n = 8). Adaptation phase took place one week before the start of testing to familiarize subjects with the testing and the procedures of training. All subjects took part in the warm up and cool down sessions before and after the testing and the training for 5 minutes each. Health and fitness questionnaires were provided for all participants to understand, note the subject's health status, physical activity and food habits.

Procedures and Measurement

The current study was undertaken from February to April (8 weeks) in the KFUPM Gymnasium.

The body composition (BC) such as H; was measured while, the subject was barefooted by a Stadiometer to the nearest cm and BM, BMI, BF%, FFM and TBW were measured by TANITA DC430 MAP, Japan. The body dimension (BD) circumferences of calf (right & left), Thigh (right & left), shoulders, and chest were measured by a tape. The one repetition maximum (1RM) test was assessed for all groups in seated LP, horizontal CP, seated SP, seated LE, and seated PD [36]. The metabolic measurements (MM) were assessed at week 1, 3 and 6 for all groups. The total daily energy requirement (TDER) was calculated at week 1, 3 and 6 (21), as follows:

662 - 9.53 (age in years) + physical activity (1.2) [15.91 (weight in kg) + 539.6 (height in meters)]. A week before the start of the RT program, all food items in the food center of KFUPM were weighed and calories were assessed. Then, Food questionnaires were drafted to all subjects who were asked to tick mark the food items that were consumed for three meals. The calculation of the TDFI took place before the start of the training program for the purpose of finding out the TDFI deficiency. If there was a TDFI deficiency, the subjects of CRIFIG-1 and IFIG-3 were asked to add the appropriate amount of food to their meals till the end of the training. While, CRNFIG-2 and NFIG-4 were asked to continue their normal TDFI. The calculation of TDFI also took place in week 3 and 6. The total daily energy expenditure (TDEE) was calculated in week 1, 3, and 6 as follows: BMR = 88.362 + (13.397 x weight in kg) + 4.799 x height in cm) – (5.677 x age in years). TDEE = BMR X PA (1.2) [36]. The resistance training (RT) drills were the CP, PD, LE, LP, and SP [36]. In week 1 and 2, the subjects performed 80% of 1RM with 8-10 reps. In week 3 and 4, the intensity was increased to 85% with 6-8 reps. In week 5 and 6, the intensity was 90% with 4-6 reps. In week 7, the intensity was 95% with 2-4 reps. In week 8, the intensity was reduced to 70% for the purpose of recovery before the week of testing with 8 reps. The RT consisted of 3 sets for each exercise with a rest of 1-2 min between sets. CRIFIG-1 and CRNFIG-2 only performed the RT program in this study. Mean and

standard deviation were calculated for all values using SPSS version 16.0 software. The Paired t-test was used to identify any significant difference within each group independently for the dependent variables. To compare the differences between all groups at pre-test, post-test, and mean differences (post-tests – pre-tests), the ANOVA was used. The repeated measures were utilized to find out the main effect for group, time and the interaction effect of time by groups for the MM. Scheffe test was used to distinguish the differences between unequal sample size groups. The level of confidence was set at $P \leq 0.05$.

RESULTS

80 subjects (n = 20 in each group) participated at the beginning of the study, but several of them dropped out due to various reasons and 47 participants completed the study.

Body Composition (BC)

Table 1 of BC showed similar values between groups at pre and post-tests ($P > 0.05$). CRIFIG-1 and CRNFIG-2 had greater mean differences (post-pre) than IFIG-3 and NFIG-4 in FFM ($P < 0.016$); however, no changes were observed in the remaining variables ($P > 0.05$). Increases of 1.6% ($P = 0.013$) in FFM and 1.1% in TBW ($P = 0.031$) were shown in CRIFIG-1. CRNFIG-2 rose by 1.8% in BM ($P = 0.009$), 1.8% in BMI ($P = 0.008$) and 2.2% in FFM ($P = 0.008$). IFIG-3 elevated by 1.2% in BM ($P = 0.038$), 1.5% in BMI ($P = 0.027$) and 1.6% in TBW ($P = 0.001$), but no changes were reported for NFIG-4 in all BC variables ($P > 0.05$).

Table 1- Body Composition

Variables	Tests	CRIFIG-1	CRNFIG-2	IFIG-3	NFIG-4	P-Values
Age (y)	Pre	18.75±0.68	18.80±0.77	18.89±0.33	18.62±0.74	0.875
Height (cm)	Pre	171.06±5.54	171.33±6.18	167.67±5.63	173.38±3.15	0.197
BM (kg)	Pre	50.83±4.56	50.31±4.57	49.88±3.57	52.56±3.04	0.569
	Post	51.38±4.81	51.26±4.96	50.51±3.82	52.61±2.98	0.809
	Post-Pre	0.55±1.77	0.95±1.21	0.63±0.75	-0.76±3.34	0.212
BMI (kg/m^2)	Pre	17.34±0.97	17.12±0.79	17.68±0.76	17.46±0.65	0.439
	Post	17.57±1.07	17.43±0.89	17.95±0.75	17.50±0.71	0.586
	Post-Pre	0.23±0.63	0.31±0.38	0.27±0.29	0.12±0.28	0.825
BF (%)	Pre	8.47±3.01	8.36±4.27	7.73±2.75	8.28±3.50	0.964
	Post	7.96±3.35	8.54±4.46	7.80±2.55	8.73±3.64	0.924
	Post-Pre	-0.51±1.75	0.18±1.18	0.07±1.34	-0.06±0.32	0.404
FFM (kg)	Pre	46.48±3.92	45.96±2.96	45.96±3.15	47.86±2.61	0.581
	Post	47.23±3.97	46.71±2.99	46.47±3.40	47.97±2.60	0.788
	Post-Pre	0.75±1.06	0.75±0.93	0.51±0.92	-0.18±0.45	0.015*
TBW (kg)	Pre	35.32±2.38	34.94±1.99	35.24±2.14	35.93±1.76	0.769
	Post	35.71±2.25	35.38±2.22	35.81±2.25	36.00±1.52	0.916
	Post-Pre	0.39±0.65	0.44±0.80	0.57±0.30	-0.18±0.65	0.200

*: Significant for mean difference, y: years, Kg: kilogram, Kg/m^2: kilogram per square meter, cm: centimeter, ±: Standard Deviation, Pre: Before Training, Post: After Training, Post-Pre: Mean Differences, P-values: probability of significance (ANOVA)

Body Dimension (BD)

Table 2 of BD exhibited no changes between groups before and after training (P > 0.05) or when the post-tests were subtracted from the pre-tests (P > 0.05); in addition, no changes were noticed in each group independently (P > 0.05).

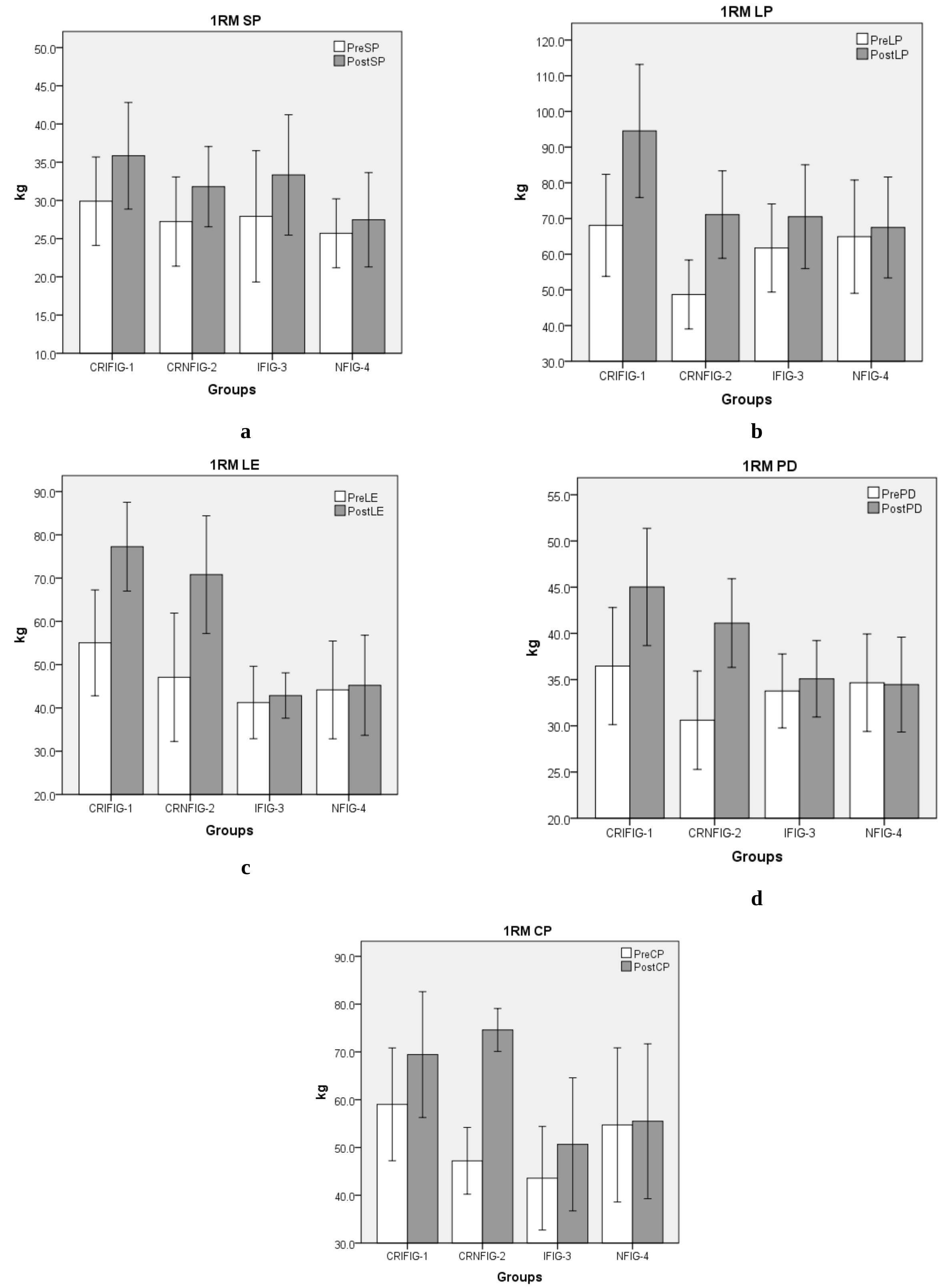
Table 2- Body Dimension

Variables (cm)	Tests	CRIFIG-1	CRNFIG-2	IFIG-3	NFIG-4	P-Values
Right Calf	Pre	31.15±1.31	30.35±1.33	31.66±1.87	30.68±2.03	0.240
	Post	31.50±1.30	30.42±1.47	31.94±1.94	30.81±2.13	0.135
	Post-Pre	-1.62±0.53	0.07±0.80	0.28±0.44	0.13±0.44	0.621
Left Calf	Pre	31.28±1.62	30.50±1.42	31.94±1.94	30.43±1.91	0.162
	Post	31.46±1.53	30.71±1.31	32.05±2.02	30.43±2.16	0.157
	Post-Pre	0.18±0.54	0.21±0.61	0.11±0.33	0.00±0.46	0.799
Right Thigh	Pre	46.00±3.20	45.78±2.42	41.22±3.90	44.37±2.88	0.165
	Post	46.16±3.30	45.71±2.32	42.72±1.56	44.37±2.56	0.092
	Post-Pre	0.16±0.52	-0.07±0.18	1.50±3.43	0.00±0.46	0.126
Left Thigh	Pre	45.23±2.69	45.25±2.75	43.55±1.04	44.31±2.80	0.346
	Post	45.50±2.73	45.21±2.71	43.72±1.09	44.25±2.86	0.330
	Post-Pre	0.27±0.49	-0.04±0.13	0.17±0.25	-0.06±0.32	0.071
Shoulder	Pre	99.78±5.04	98.75±5.27	99.00±4.13	99.50±3.77	0.940
	Post	100.40±4.87	99.46±4.20	98.94±4.15	99.31±3.79	0.853
	Post-Pre	0.62±1.29	0.71±1.70	-0.06±0.30	-0.19±0.45	0.230
Chest	Pre	78.59±4.90	79.35±3.41	77.72±3.80	77.93±2.78	0.764
	Post	80.53±4.69	79.50±2.7	78.05±4.00	77.75±2.96	0.273
	Post-Pre	1.94±1.63	0.15±1.53	0.33±0.55	-0.18±0.35	0.671

cm: centimeter, ±: Standard Deviation, Pre: Before training, Post: After training,
Post-Pre: Mean Differences, P-values: probability of significance (ANOVA)

Resistance Measures (RM)

In 1RM SP (Figure 1a**)**, CRIFIG-1 increased by 19.9% (P < 0.001), CRNFIG-2 by 16.8% (P = 0.000), while, IFIG-3 and NFIG-4 had no changes (P > 0.05). There were also no differences between groups at pre, post or post-pre tests (P > 0.05). In 1RM LP, CRIFIG-1 had greater mean differences (post-pre) than IFIG-3 (P < 0.011) and NFIG-4 (P < 0.001). CRNFIG-2 also displayed higher mean difference than NFIG-4 (P < 0.006). CRIFIG-1 increased by 38.8% (P < 0.001) and CRNFIG-2 by 45.9% (P < 0.001). While, no differences were presented between or within IFIG-3 and NFIG-4 (P > 0.05) (Figure 1b). 1RM LE (Figure 1c) exposed that CRIFIG-1 and CRNFIG-2 had higher mean differences than IFIG-3 (P < 0.05) and NFIG-4 (P < 0.05). CRIFIG-1 enlarged by 40.3% (P < 0.001) and CRNFIG-2 by 50.3% (P < 0.003); however, IFIG-3 and NFIG-4 revealed similar results (P > 0.05). In Figure 1d, the 1RM PD illustrated that CRIFIG-1 and CRNFIG-2 had enormous mean differences than IFIG-3 (P < 0.05) and NFIG-4 (P < 0.05). CRIFIG-1 raised by 23.4% (P < 0.001), CRNFIG-2 by 34.3% (P < 0.001), but, IFIG-3 and NFIG-4 had no changes (P > 0.05). The 1RM CP (Figure 1e) indicated that CRNFIG-2 had extensive mean differences than NFIG-4 (P < 0.025); however, no changes were seen between the remaining groups (P > 0.05). Increases of 17.6% (P < 0.001) were reported in CRIFIG-1 and 26.9% (P < 0.001) in CRNFIG-2; but, similar values were shown in IFIG-3 and NFIG-4 (P > 0.05).



e

Figure1 a. SP, **b**. LP, **c**. LE, **d**. PD & **e**. CP mean values (± S.D) for 4 groups measured at pre and post-training

Metabolic Measures (MM)

There were no training effects on TDER and TDEE for groups (P > 0.05) or for time (P > 0.05) and no interaction of time by groups (P > 0.05) (Figure 2a, 2b, respectively). The TDFI revealed a training effect for time (P < 0.001); week 3 and 6 showed greater total values than week 1 (P < 0.05); however, there was no change between week 3 and 6 (P > 0.05). There was also no training effect for groups (P > 0.05). Besides, there was no interaction effect of time by groups (P > 0.05) (Figure 2c). As seen in Figure 2d, the TDER showed higher values than the TDFI in CRIFIG-1, CRNFIG-2, IFIG-3 and NFIG-4 (P < 0.001). It is also stated that IFIG-3 had a higher value in TDEE in comparison with the TDFI (P < 009); however, there were no changes for the remaining groups (P > 0.05). In addition, all groups confirmed greater values in TDER in contrast with TDEE (P < 0.001).

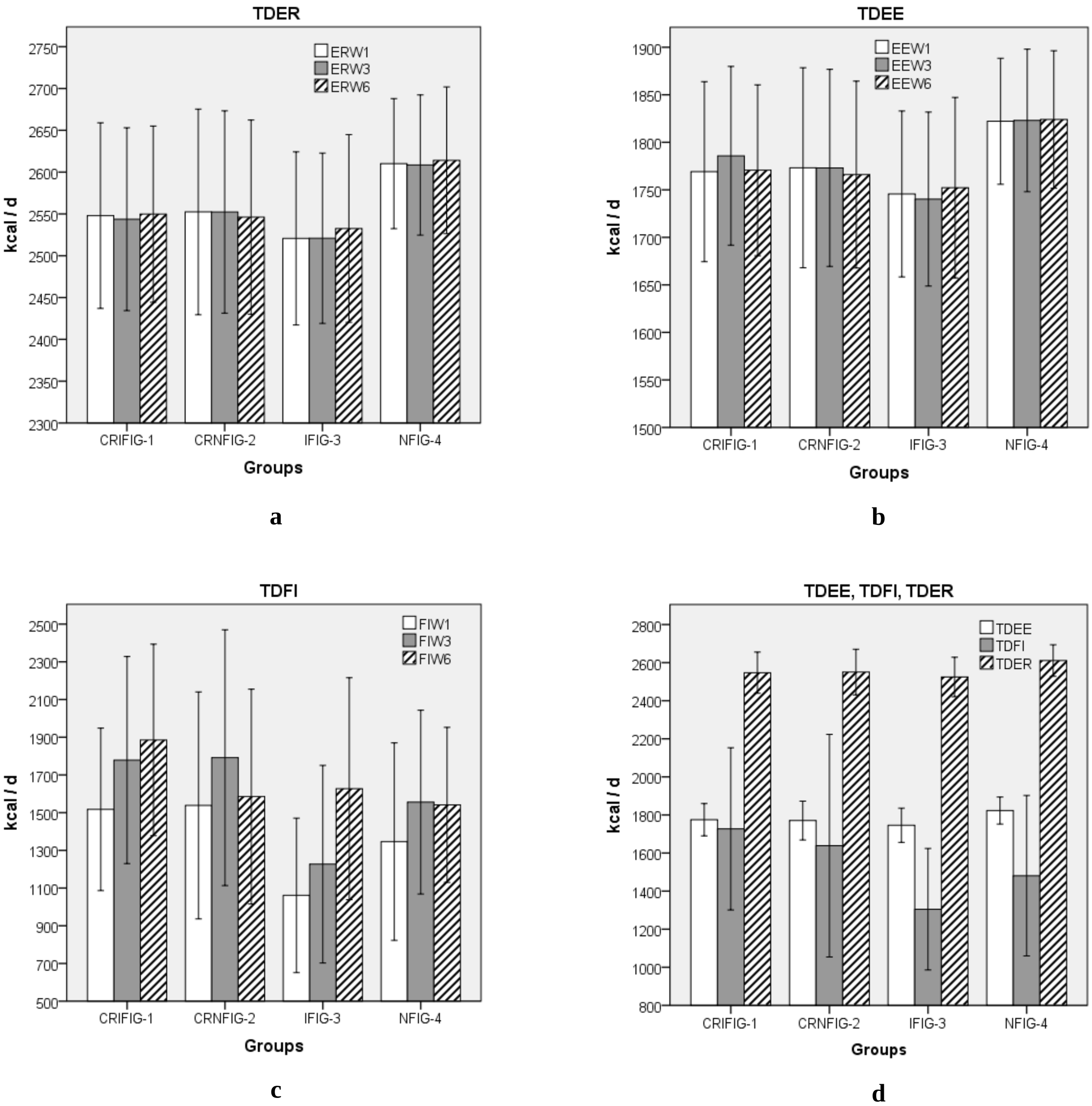


Figure2: a. TDER, **b**. TDEE, **c**. TDFI mean values (± S.D) for 4 groups measured at week 1, 3 & 6 and **d**. TDEE, TDFI and TDER mean values (± S.D) of 3 weeks for 4 groups

DISCUSSION

Our study assumed that the underweight subjects who combined increased TDFI with RT will increase their BC, BD and MM. Our subjects were genetically underweight and had a low appetite to eat enough food. They have been underweight since birth to the age of 18 which structured their life style deeply. These complications were the limitations in this study. Our findings indicated that similar training effects were observed for BC and BD measures between and within groups as indicated by Campos et al. (2002). But Bratland-Sanda et al. (2012) and Habibzadeh, (2011) showed increases of 7 and 1%, respectively in BM. In addition, significant rises in FFM were noticed by 2% [27], 3% [33] and 1% [34]. In TBW, a meaningful increase of 9% was found [34]. Similar changes were confirmed when the TDFI was compared with the TDEE or the TDER in our study, which are in line with Naclerio et al. (2013), Mayhew et al. (2010) and Hermassi et al. (2011). However, several studies reported greater TDEE than TDFI [3;5,7,11]. TDFI of 1904 kcal/d and TDEE of 2153 kcal/d were seen in elite female soccer players with a BMI of 22.1 kg/m^2 [9]. The elite Kenyan endurance runners with a BMI of 18.3 kg/m^2 registered 3146 kcal/d of TDFI and 3492 kcal/d of TDEE resulting in an energy deficiency of -346 kcal/d . Another study also confirmed TDFI of 2987 kcal/d and TDEE of 3605 kcal/d in elite Kenyan distance male runners with a BMI of 19.2 kg/m^2 leading to a deficiency of -618 kcal/d [4]. The interpretation of these controversies may be due to the fact that all the subjects in our study were genetically and habitually underweight and hence, unable to increase their TDFI. The average TDFI for all subjects was 1576 kcal/day. They also were incapable to meet the standard TDER of 2554 kcal/day. The variation between the TDER and the TDFI was about 1000 kcal/day. To approach the energy balance for normal weight subjects, the TDEE should be similar to the TDFI. In our study, the subjects were underweight which means that to increase their BM and their TDFI, they should exceed the TDER, while, the previous investigations utilized mostly normal weight elite athletes. Only one study used underweight male elite Kenyan endurance runners who found a significant energy deficiency of -346 kcal/d. All the RM revealed training effects when the paired t-test were used. Our findings agreed with several studies [24,25,26,27,28] who stated increases in the 1RM LP by 66, 27, 18, 26 and 62%, respectively, after RT. An increment of 27, 53, 30 and 16% were observed in 1RM LE [24,26,29,30]. In 1RM CP, raises of 32% [31], 39% [27], 19% [32], 12% [33], 14% (26) and 20% [28] were reported. In 1RM PD, a rise of 6% was found (20). Our study confirmed a greater increment in RM than some previous studies [25,26,29,30,32,33]. While, increases of 66, 62, 32 and 39% [24,27,28,31] respectively were confirmed in RM more than our study. The use of untrained normal weight men who were longer (178, 183 cm) and heavier (77.8, 81.6 kg) may explain the superior elevations [24,28] respectively. While, the use of underweight females for longer training periods (12-16 weeks) may interpret the results of Mayhew et al. (2010) and Bratland-Sanda et al. (2012). The subjects with lower fitness levels are able to increase their performances greater than the subjects who have higher fitness levels. In our study, the underweight subjects had lower strengths than the normal weight elite or trained athletes. The increase in RM belongs to the enhancement of the central nervous system rather than the hypertrophy. To gain strength, a short training mode was needed and all underweight subjects in our study had atrophy in the shoulders, which clarify the result of the 1RM SP.

CONCLUSION

In our study, interesting findings were observed. Firstly, the high intensity RT is not advisable, instead, a moderate regime may enhance underweight strength. Secondly, they need more supervision to perform properly the RT. Further, they had less appetite for eating; therefore, adding appetizers to the food may improve their TDFI. Hence, focusing on underweight subjects with no hereditary difficulty is more convenient than those who are genetically underweight.

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