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The Effect of Chicken Formulations on Muscle Mass and Strength in Thai Healthy Male Volunteers

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Abstract

This study aimed to examine the effect of high protein from chicken breast products during resistance exercise training on muscle mass and strength in healthy Thai male volunteers. In this study was double-blind randomized placebo-controlled study. This study assessed changes in muscle mass and strength of 60 healthy men aged 20-35 years with normal BMI (23.04±2.52 kg/m2). Participants were randomly divided into three groups receiving controlled placebo tablet (CG, n=18, lactose-based containing 12.0 g lactose/day), chicken tablet (CT27, n=18, 27.0 g protein/day), and chicken chip (CC36, n=19, 36.8 g protein/day) during 69-day period. In addition, all groups were instructed to perform the same resistance training program (4 times per week). Body composition (BIA), anthropometry (AMC, CMC), and muscle strength were measured. After 9 weeks of the study, CC36 group had a statistically significant increase ($p<0.05$) in the percentage of skeletal muscle from baseline when compared other two groups. Additionally, a significant increase ($p<0.01$) in arm muscle circumference, back-leg extension, and hand grip strength were observed in both groups receiving chicken protein products. The same result was also detected in the placebo group but at a much slower rate. Resistance training exercise along with intake of the chicken protein products could increase muscle mass and strength.

Keywords: *Chicken breast protein, Body composition, Anthropometry, Muscle strength, Double-blind study*

Introduction

Protein is an essential nutrient that plays a primary role in body metabolism as an essential component of tissues, hormones, and enzymes (Hoffman et al., 2004). Daily protein consumption can be taken from various sources, such as animals, plants, and milk (Hartman et al., 2007; Hoffman et al., 2004). Protein is the most needed nutrient for people who exercise regularly or athletes (Kårlund et al., 2019; Pasiakos et al., 2015). Beyond normal dietary protein intake, the benefits of additional protein consumption for people of all ages participating in resistance training are to help the body be repaired after exercise, maintain muscle mass, and increase power and strength (Helms et al., 2014; Pasiakos et al., 2015). Because of the high demands for protein in athletes, assorted supplements such as snacks, drinks, powder, and tablets are valuable useful alternatives for those who cannot obtain adequate protein from daily diet (Kårlund et al., 2019).

Animal meat is a significant source of protein supplement ingredient due to the rich in essential amino acids, which helps synthesize muscle and is essential to the net processes within the body more than other sources (Berrazaga et al., 2019; Hoffman et al., 2004). Diets consisting of meat result in greater

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gains in lean body mass than subjects on a lactoovovegetarian diet (Campbell et al., 1999). High protein diets from the animal sources have also been shown to cause a significantly greater net protein synthesis than a high vegetable protein diet (Berrazaga et al., 2019). Currently, protein supplements in various forms such as powder, tablets, snack bars, and chips are prevalent because they can be consumed easily. Several effects of protein supplements on human body have been reported (Cintineo et al., 2018; Mertz et al., 2021). For example, 46 grams of beef, chicken, and whey protein compared to a maltodextrin control on lean mass and strength during 8 weeks of resistance training were reported to enhance lean body mass and reduce fat mass in young males and females (Sharp et al., 2018). High-protein snacks from dried egg white efficiently increase the mass and strength in human muscle (Kato et al., 2011).

Chicken products, including fresh meat, are famous worldwide since it is convenient, cheaper than others due to the cost of production, and quick to prepare (Erian et al., 2017). In addition, chicken meat contains various nutritional benefits such as being low in fat and saturated fat (Kralik et al., 2018). Chicken breast meat is a complete protein source that contains all twenty-two amino acids required to build protein-based structures such as muscle, hair, skin, and other connective tissues (Hoffman et al., 2004; Marangoni et al., 2015). Additionally, it contains creatine, a non-essential amino acid used to produce energy for stronger contractions in muscles, increasing lean muscle mass, and improving performance in bodybuilders and athletes, in the same amount as beef and lamb meat (0.4 grams of creatine/100 g of cooked chicken breast) (Kaviani et al., 2020). Leucine, isoleucine, and valine, a group of three branched-chain amino acids (BCAAs) involved in stimulating muscle growth, are also abundantly found in chicken breast (Zhang et al., 2017).

Several studies have examined the influence of protein supplementations, mostly in the form of whey protein or planted-based protein snacks, on muscle mass and strength, but not for meat-based protein (Brown et al., 2004; Grubic et al., 2019). Furthermore, protein snacks are usually high in salt and fat, which adversely affect the body and are expensive. Therefore, in this work, the effects of two snack formulations of chicken breast meat (CT27, Chicken Tablet containing 27.0 g of chicken protein/serving/day VS CC36, Chicken Chip containing 36.8 of chicken protein/serving/day) with low salt (not exceeding to 180.7 mg/serving) on body composition, anthropometry, and muscle strength of people involved in a resistance-training program were studied in people involved in a resistance-training program of 69 days.

Methods

Participants

Sixty Thai male subjects aged 20-40 years were recruited for this double-blind, randomized, clinical trial. Participant should be physical activity 3–4 days a week for at least two months before the study, have Weight stable (±2 kg) for at least two months before the study and Body mass index (BMI) between 18.5 to 29 kg/m^2. Prior to the commencement of the study, a complete explanation of the purpose and procedures of the investigation was given to the participants who were requested to sign a written informed consent document. This followed the protocol approved by the Institutional Review Board of Naresuan University (NUIRB) (COA No.061/2019; Approval Date: January 21, 2019), which complies with the Declaration of Helsinki revised in 1983.

The participants were required to maintain a food diary for the three days immediately prior to the start of the experiment. On the first day of the experiment, the 3-day food diary was analyzed, a clinical history was elicited from each participant, and all participants underwent a physical examination. Volunteers with metabolic or cardiovascular abnormalities, musculoskeletal injuries, who were current tobacco users or were currently using protein supplements or taking medication that would affect protein metabolism, or had food allergies, were excluded.

Experimental protocol

This study was designed to assess the effects of protein from chicken breast products intake on muscle mass and strength. Using a randomized design, the participant received either chicken tablet product, chicken chip product, and placebo by random allocation using a 'block of four' prior to the 3-day food diary was analyzed. Participant, investigator, laboratory staff and data extraction staff were blinded to allocation until all data was analyzed. The participants were assigned to a group that received placebo tablets as the control group (CG, n=18, lactose-based formulation containing 12 grams lactose/serving/day), a second group received Chicken Tablet (CT27, n=18, 27.0 grams of protein/serving/day), and the third group received Chicken Chips (CC36 n=19, 36.8 grams of protein/serving/day). Each serving of supplements was to be taken on every day of the 69-day period of the study. Also prior to commencement, daily practice manuals regarding diet and strength training exercises, including daily eating records and exercise records, were provided.

Participants were required to perform resistance-type exercise on each of the four workout days/week to maintain muscular levels. On each workout day, participants were instructed to consume half of their serving of supplements 30 minutes before their workout and the other half immediately following their workout. On each resting day (no workout on these days), the participants were instructed to consume the placebo and supplement twice, once at about 10 am. and then again at about 3 pm. Three ordinary meals per day were assumed. On the first day of the study, baseline measurements of vital signs, body composition, anthropometry (mid-arm and calf circumferences), muscle strength testing, and nutritional consultation were taken. On days 23 and 46, and on the final day of the study, day 69, participants were again assessed to check vital signs, body composition analysis (weight, body mass index, total body fat percentage, and the percentage of skeleton muscle mass), with anthropometry, muscle strength, and nutrition assessment. The trial was conducted at the Exercise and Rehabilitation Sciences Research Unit, Faculty of Allied Health Sciences, Naresuan University, Phitsanulok, Thailand. The complete food and exercise records were recalled from the participants on the final day, and any adverse reactions or adverse effects experienced by the participants were identified and discussed.

Dietary analysis and supplementation protocol

Participants were instructed to maintain their habitual diet and complete a 3-day food diary on five occasions: first, immediately prior to the initial baseline testing day, and subsequently immediately prior to days 23, 46 and 69 (which was the last day of the testing period). The participants had been given detailed instructions recording their normal diet which was to encompass 3 consecutive days each time, including 2 weekdays and 1

Table 1. Demographic and baseline muscle characteristics of subjects (N = 55).

Characteristic	Placebo	Chicken tablet	Chicken chip
n	19	18	18
Age	23.05±3.50	22.76±3.87	22.75±3.57
BMI	24.21±2.81	23.59±3.10	21.31±1.66
Vital sign			
Blood pressure (mm/HG)			
Systolic	129.8±12.5	128.2±8.0	122.7±10.9
Diastolic	74.6±7.0	73.3±6.8	72.2±8.3
Heart rate (beats/min)	69.6±7.9	70.1±6.4	78.7±12.2
Body temperature (°C)	36.77±0.24	36.75±0.25	37.15±0.25
Body composition			
Total fat (%)	18.69±1.11	19.83±1.36	16.38±0.71
Skeletal muscle (%)	35.47±0.47	35.09±0.61	36.01±0.34
Anthropometry			
Arm muscle circumference	28.99±0.86	29.80±0.67	27.69±0.86
Calf muscle circumference	35.15±0.72	34.90±0.56	33.98±0.48
Muscle strength			
Back extension (kg)	106.86±6.83	104.25±7.61	95.71±5.49
Leg extension (kg)	112.08±8.68	98.17±7.89	93.18±6.18
Hand grip (kg)	40.29±1.45	39.34±1.83	37.02±1.27

Note Values are means±SEM, Homogeneity was determined using analysis of variance

weekend day (on the assumption that their weekend diet may vary from their weekday diet). These records were used to estimate total daily energy expenditure (TEE) to compare against nominally required kilocalories, using the Harris-Benedict equation for persons with a physical activity level of 1.5.

BEE (for men) = 66.47 + (13.75×Weight(kg)) + (5.00×Hight(cm)) - (6.75×Age(years))

TEE = BEE×Activity factor×Stress factor

The dietary intake data was collected and estimated using the INMUCAL-Nutrients software, version 4 (Kittisakmontri et al., 2021), developed by the Institute of Nutrition, Mahidol University, Thailand.

Training program

The training program was resistance-type exercises for 1 hour on 4 days per week for each of the 9 weeks (69 days) of the study period. Each day's session began with about five minutes of warm-up on a cycle ergometer or treadmill, followed by five to ten minutes of flexibility training and then a sixty-minute resistance training period. Each of the four sets of resistance exercises was undertaken with twelve repetitions at 80% of 1RM (repetition maximum) (Krzysztofik et al., 2019). The resistance training protocol included pectoralis and triceps exercises on the first day, back and biceps exercises on the second day, deltoids on the third day, and quadriceps, hamstrings, and calves on the fourth day (Thomas et al., 2016). Training logs were maintained that recorded each participant's completion of the number of repetitions, sets, and loads for the workout session. These logs were then reviewed at the end of each day by the training staff.

Measurements

Body composition

An Omron Body Composition Monitor (HBF-375, Omron Cooperation, Tokyo, Japan) was used to assess bioelectrical impedance. Measurements were collected at 50 Hz using the standard settings based on the height, gender, and age of the participants. The participants were barefoot and were posed with outstretched arms and feet touching all four metal plates of the monitor.

Anthropometry

Calf circumference is commonly measured with a tape at the point of the greatest circumference of the calf. The left leg is measured for naturally right-handed persons with the person in a sitting position with both feet flat on the floor and knees bent at a right angle. Calf circumference was taken to the nearest 0.1 cm. Caution was taken to avoid compressing the subcutaneous tissue.

The mid-arm circumference was measured with a measuring tape on the upper arm, at the mid-point between the olecranon process of the shoulder and the acromion, with the participants in a seated position. The measure was accurate to the nearest 0.1 cm. The triceps skinfold thickness was measured using a calibrated skinfold caliper (range 0.00–50.00 mm; minimum graduation 0.2 mm). Skinfold thickness was recorded to the nearest 0.2 mm. For both these parameters, an average of three measurements was calculated.

Muscle strength measurement

Assessment of leg strength

Participants, wearing training shorts, stood on the footplate of the Takei dynamometer (Takei Scientific Instruments Co., Ltd, Tokyo, Japan) with their scapulae and buttocks positioned flat against a wall. The back of the footplate was approximately 15 cm from the wall. Participants flexed their legs, sliding down the wall until the leg extension angle equaled 135' (2.36 rad). Participants then reached down with the elbows fully extended. The pull-bar of the dynamometer was placed in the hands and the chain length was adjusted appropriately. Participants were instructed to extend the legs with maximal effort, pulling the bar smoothly without 'jerking'. The highest of three scores was recorded.

Table 2. Dietary intake in healthy male participants.

Variable	Time period		Chicken protein products 2 times/day
	Baseline	At day 69	
Total energy, kcal/d			
CG	1453.8±183.3	1523.9±170.7	115.6
CT27	1426.1±163.4	1416.9±52.9	121.8
CC36	1567.1±85.9	1482.6±79.9	251.6
Protein intake			
Absolute, g/d			
CG	82.9±10.3	81.4±6.9	0.0
CT27	79.2±13.0	76.8±8.3	27.0
CC36	79.7±5.1	100.3±15.7	36.8
Relative, g/kg/d			
CG	1.11±0.14	0.96±0.08	0.00
CT27	1.18±0.23	1.23±0.12	0.43
CC36	1.20±0.05	1.37±0.17	0.50
Carbohydrate intake			
Absolute, g/d			
CG	158.7±21.9	149.5±25.8	27.8
CT27	164.8±23.1	151.5±7.0	13.6
CC36	145.4±16.6	135.2±18.1	11.4
Relative, g/kg/d			
CG	2.07±0.30	1.76±0.31	0.32
CT27	2.45±0.43	2.42±0.11	0.21
CC36	2.20±0.22	1.85±0.22	0.15
Fat intake			
Absolute, g/d			
CG	54.2±8.1	66.7±12.7	0.0
CT27	50.0±4.0	55.9 ± 5.0	4.4
CC36	74.1±8.1	60.1±11.6	6.6
Relative, g/kg/d			
CG	0.76±0.11a	0.79±0.16	0.00
CT27	0.77±0.08a	0.70±0.10	0.07
CC36	1.13±0.15b*	0.82±0.16*	0.10

Note Values are mean±SEM, a different from b, 1-way ANOVA, *p<0.05.

Assessment of back strength

Participants stood on the footplate of the Takei dynamometer, initially in the same manner as for the measurement of leg strength. The legs were kept straight and the back was flexed at the hip. Flexion continued until, with fully extended elbows, the tips of the index fingers reached the patellae. The pull-bar of the dynamometer was then placed in the hands and the chain length was adjusted. A reverse grip was adopted for the measurement of back strength to deter the use of shoulder muscles during the 'pull'. The highest score from three pulls was recorded.

Assessment of handgrip strength

The Takei T.K.K.5401 GRIP-D handgrip dynamometer (Takei Scientific Instruments Co., Ltd, Tokyo, Japan) was used to measure the handgrip strength, which is a simple and popular test for general strength levels. Each participant squeezed the dynamometer handgrip for 3 s, twice in succession without rest. The highest 'squeeze strength' value was recorded. There for, quantitative variables were measured.

Statistical analysis

All data were expressed as the mean±standard deviation. Baseline participant characteristics are described using common descriptive statistics, and a 1-way ANOVA was used to confirm homogeneity between groups. Changes in body composition and muscle strength as a response to consuming the dietary supplement were calculated to determine differences over time between diet groups. All outcome variables were analyzed using a mixed-model repeated-measures ANOVA including within-subjects factors for time (study days) and with a between-subjects factor of diet group (placebo, chicken tablet, and chicken chip). Where a significant interaction between these variables was observed, post hoc pairwise analyses were conducted using Bonferroni adjustments for multiple comparisons. The level for significance was set at $p<0.05$. Data were analyzed using SPSS 25 for Windows (Chicago, IL).

Results

Flow of subjects through the study

Three subjects did not meet the criteria. As a result, fifty-seven subjects were enrolled. During the study for 9 weeks, two subjects were lost to follow up with their own personal reason that not involved with this study. Finally, fifty-five subjects completed the study. Flow of subjects through the study is shown in Figure 1.

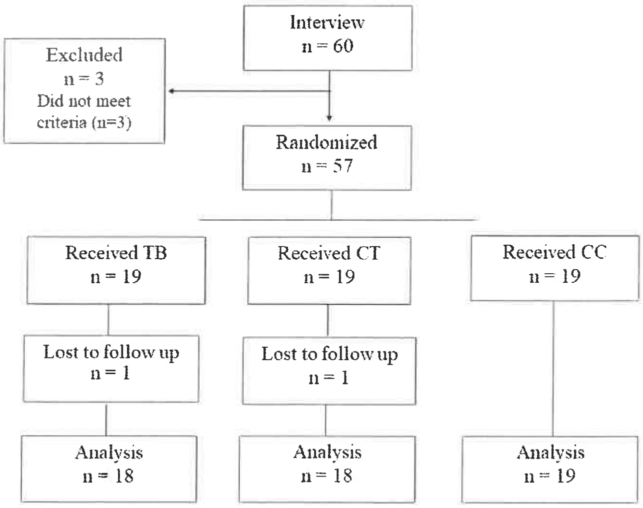

FIGURE 1. CONSORT (Consolidated Standards of Reporting Trials) diagram of study recruitment, enrollment, randomization follow-up, and analysis.

Demographic data

Table 1 shows the demographic of fifty-five subjects completed the study. The age range of subjects was 20 to 35 years (23 years in average). Almost of them are working as the university employees 32.7% and studying at the university 67.3%.

Assessment of body composition

In the following sections, reference to 'the four time points' refers to Day 0, Day 23, Day 46 and Day 69 of the study period. Day 0 is also referred to as the baseline day.

There was similarity across the four-time points ($p>0.05$) but significant differences between groups ($p<0.05$) in skeletal muscle percentage (Figure 2a). There was also a significant between time x group interaction ($p<0.05$). By following up this interaction, there was no significant difference between groups at baseline. However, the mean scores of the CC36 group showed a significant increase between day 69 compared with the baseline, day 23, and day 46 time periods ($p<0.05$, time x diet group interaction). For total fat percentage, there was a non-significant difference between the two dietary protein groups over time ($p<0.05$), nor was the CG group ($p>0.05$) (Figure 2b).

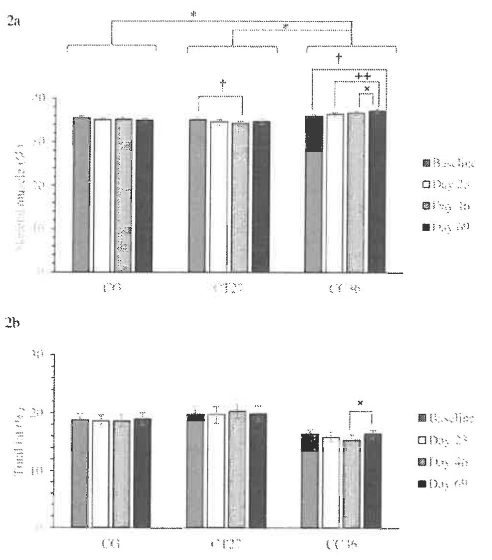

FIGURE 2. Effects of high protein from chicken breast products on percentage of skeletal muscle (2a) and total fat (2b) values. They were collected on baseline (dark gray bar), day 23 (white bar), day 46 (light gray bar), and day 69 (black bar) after the application of the tests.

Assessment of anthropometry

At commencement, there was no significant difference between groups (p>0.05), regarding arm muscle circumference. There were significant differences across the four time points (p<0.01) between all groups (Figure 3a). There was also a significant between time x group interaction (p<0.05), indicating that consumption of the two protein supplements had a significant effect with the mean scores of the CT27 and CC36 groups showing a significant and constant increase over baseline at day 23, day 46, and day 69 (p<0.01). For the within-group results for the CC36 group, there was a statistically significant increase in the arm muscle circumference value from day 23, which was observed at day 69 (p<0.05).

For calf muscle circumference, there was similarity across the four-time points (p>0.05) and significant differences between all groups (p<0.05) (Figure 3b). The mean scores of the placebo group significantly decreased after day 23.

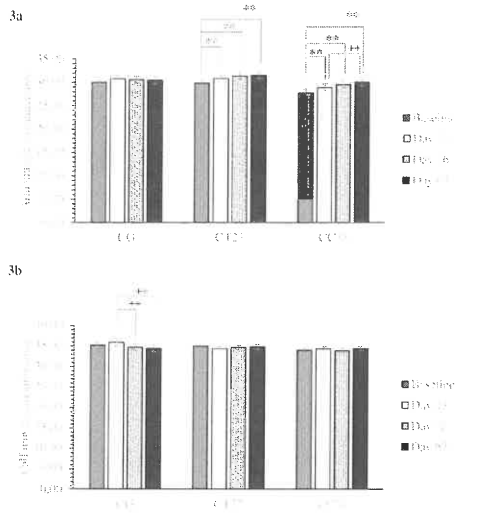

FIGURE 3. **Effects of high protein from chicken breast products on arm (3a) and calf muscle circumference (3b) values. They were collected on day 0 (baseline) (dark gray bar), 23 (white bar), 46 (light gray bar), and 69 (black bar) after the application of the tests.**

Assessment of muscle strength

The three aspects of muscle strength tested were back extension force, leg extension force, and handgrip strength.

For back extension force, at baseline, no significant differences between groups (p>0.05) were observed, and subsequently, there was no significant between time x group interaction (p>0.05). However, there was a significant difference across the four-time points (p<0.01). (See Figure 4a). However,

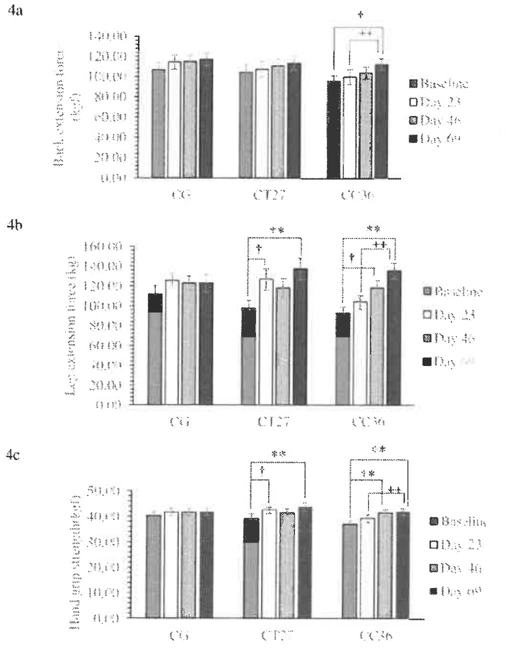

FIGURE 4. **Effects of high protein from chicken breast products on back strength (4a), leg strength (4b), and hand grip strength (4c). They were collected on day 0 (baseline) (dark gray bar), 23 (white bar), 46 (light gray bar), and 69 (black bar) after the application of the tests.**

the mean scores of the CC36 group significantly increased between baseline and day 69 ($p<0.05$), with a significant increase from day 23 compared with day 69 ($p<0.05$).

For leg extension force (kgf), there were significant differences across the four-time points ($p<0.01$) but no significant differences between groups ($p>0.05$). There was also a significant between time x group interaction ($p<0.05$). The mean scores for leg extension force of the CT27 group gradually increased overall from the baseline to day 69. For the CC36 group there was a similar overall statistically significant increase between baseline and day 69, with an accelerated increase from day 23 and 69 that was statistically significant. The leg extension results are shown in Figure 4b.

For the handgrip strength (kgf) data, there were significant differences across the four-time points ($p<0.01$) but no significant differences between groups ($p>0.05$) (Figure 4c). There was also a significant interaction between time x group. ($p<0.05$).

Overall, from baseline to day 69, the mean scores for handgrip strength of the CT27 group gradually increased from the baseline to day 69. For the CC36 group, there was a statistically significant increase overall, from baseline to day 69.

Discussion

Our double-blind placebo-controlled design study was one of the few studies which evaluated the effects of meat-based snacks on muscle mass and strength of people involved in a resistance-training program. The crucial finding of this study was that both high protein snacks from chicken breast in chip and chewable tablet forms consumed both before and after training at the level above RDA increased muscle mass in term of skeleton muscle percentage and arm muscle circumference as well as strength of legs, back, and hands (Hoffman et al., 2004; Negro et al., 2014).

The recommended daily intakes (RDIs) set by The Academy of Nutrition and Dietetics suggested that an average individual should consume 0.8 grams of protein per kilogram of body weight per day ($g \cdot kg^{-1} \cdot d^{-1}$) for general health (Lonnie et al., 2018), while people with regular exercise such as lifts weightlifting, running, or cycling event were advised to eat a range of 1.2-1.7 $g \cdot kg^{-1} \cdot d^{-1}$to increase muscle mass in combination with physical activity (Rodriguez et al., 2009). From nutritional intake data of this study, habitual protein intake along with protein from chicken breast products of participants was approximately 1.9 and 1.7 $g \cdot kg^{-1} \cdot d^{-1}$ in CC36 group and CT27 group, respectively. In comparison, it was 1.0 $g \cdot kg^{-1} \cdot d^{-1}$ in CG group.

Muscle mass was built when the net protein balance was positive: muscle protein synthesis exceeds muscle protein breakdown, and muscle protein turnover was the greatest after working out (Tipton et al., 2013). Additionally, it has been shown that muscle mass increased over time when resistance exercise (weightlifting, bodyweight exercises, etc.) was combined with nutrient intake (C. E. Cooper et al., 2008). With higher protein intake, participants appeared to increase the ability of necessary protein synthesis and inhibit protein degradation (Weinert, 2009). The increase in protein synthesis could be explained by an increase in mammalian target of rapamycin and 70-kDa ribosomal protein S6 kinase signaling initiated by positive regulators (e.g., insulin-like growth factor 1) and this pathway (Detzel et al., 2015). Shivani et.al. recently demonstrated that consuming animal-based protein containing essential amino acids could trigger the aforementioned signaling pathways to enhance protein accretion and muscle mass (Sahni et al., 2015).

Focusing on the body composition, baseline measurements of all parameters of the three groups showed no significant difference ($p>0.05$). For % skeleton muscle mass in the CT27 group, no significant changes were observed after 69 days of the study compared to the baseline value, while there was an increase in the CC36 group from the baseline to days 46 and 69 of consumption ($p<0.05$). This might be explained by the different serving protein content in the CC36 formula containing 20% higher amount of protein than the CT27 formula. High animal-based protein diets have also been shown to cause a significantly greater net protein synthesis because food protein quality assessed by digestibility, net protein utilization, and biological value has been better than other sources (Berrazaga et al., 2019; Hoffman et al., 2004).

Overall, for muscle strength assessment including back, leg and lower-hand muscle strength, showed that the strength gains of the CT27 and CC36 groups were significantly greater than that of the placebo group. Even though the muscle strength values for the placebo group tended to increase from baseline, this was a slower rate than the other groups indicating that protein intake was beneficial (Sahni et al., 2015; Sharp et al., 2018). In conclusion, resistance training exercise-induced muscular strength might be primarily mediated by dietary protein intake and strength training (Cooper et al., 2008). Load and specificity, training volume, and especially increased training experience might also contribute but were not studied here (Mangine et al., 2015). The International Society for Sports Nutrition also recommended protein intake at levels higher than the RDA for physically active individuals (1.4–2.0 g/kg/d).

Calf muscle circumference measurements showed no significant increase at all over the 3-month period for protein groups. However, interestingly, the placebo group experienced a significant decrease in calf muscle circumference over the 3-month period. The muscle strengthening exercises for calf muscles were performed only one day of each of the four exercise days per week, whereas the arm muscles benefited from all upper-body exercises. This might be because of the amount of exercise of the calf muscles was insufficient to achieve a significant outcome (Burd et al., 2010). For another explanation, given the decrease in calf muscle strength in the placebo group, it could be assumed that consumption of the protein supplements did have a beneficial effect on calf muscle strength, of only to maintain initial strength.

Similar outcomes have been reported not only in biceps and triceps workout that direct affected biceps and triceps muscle groups but also back, chest, and deltoid workout that minor affected biceps and triceps muscle groups (Andersen et al., 2014; Atle Hole Saeterbakken et al., 2017). The limited effect of only one exercise day on calf muscles was also noted. To build muscle more uniformly, workouts needed to be performed concurrently and consistently with all muscle groups over time (Crewther et al., 2016; Mangine et al., 2015).

However, the percentage of total fat of the CC36 significantly increased ($p<0.05$) between day 46 and day 69. Although protein offers a number of health benefits, a diet with excess calories will be converted to fat glucose (by gluconeogenesis) or ketone bodies. The leftover carbon compound is also converted into glucose, which the human body uses for energy. In a state of low energy demand, these metabolites will be stored as glycogen and fat (Bray et al., 2012).

Nevertheless, the present study had limitations, including gender, race, and source of protein, confining potential generalizability. Gender is an important consideration in responses to interventions for body composition changing and muscle adaptations. A small number of participants might provide less consistent results than a larger one. Longitudinal studies of changes in dietary protein, lean mass, and strength should be explored because future prospects for interventions will depend on identifying these physiologic pathways involved in muscle changes with age.

Conclusion

This study shows the consumption of chicken protein as a high protein snack promotes the building and strengthening of human muscle when taken during a regular strength training program. Therefore, it is reasonable to suggest that, to popularize these as desirable edible product, further research is required to be improve the smell and taste of the products.

Conflicts of interest: There are no conflicts to declare.

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