Journal of Exercise Science & Fitness 19 (2021) 189–194

Contents lists available at ScienceDirect

Journal of Exercise Science & Fitness

journal homepage: www.elsevier.com/locate/jesf

Gum chewing while walking increases walking distance and energy expenditure: A randomized, single-blind, controlled, cross-over study

Yuka Hamada [a], Chihiro Nagayama [b], Kyoko Fujihira [b], Yusei Tataka [b], Ayano Hiratsu [b], Kayoko Kamemoto [a], Kanako Shimo [c], Susumu Kanno [c], Kenji Osawa [c], Masashi Miyashita [d, *]

[a] Waseda Institute for Sport Sciences, Waseda University, Saitama, Japan
[b] Graduate School of Sport Sciences, Waseda University, Saitama, Japan
[c] Central Laboratory, Lotte Co., Ltd., Saitama, Japan
[d] Faculty of Sport Sciences, Waseda University, Saitama, Japan

ARTICLE INFO

Article history:
Received 6 December 2020
Received in revised form
12 April 2021
Accepted 18 April 2021
Available online 7 May 2021

Keywords:
Energy expenditure
Gum chewing
Physiological parameters
Walking

ABSTRACT

Background/objective: Gum chewing while walking increases walking distance and energy expenditure in middle-aged male and female individuals. This study aimed to examine the effects of gum chewing while walking on walking distance and energy metabolism in male and female individuals of various age groups.
Methods: Fifty participants (25 male and 25 female individuals) aged 22–69 years completed two trials in a random order. In the gum trial, participants walked at a natural pace for 15 min while chewing two gum pellets (1.5 g, 3 kcal per pellet) following a 50-min rest period. In the tablet trial, participants rested for 50 min before walking, and the participants then walked at a natural pace for 15 min after ingesting two pellets of tablet containing the same ingredients with the exception of the gum base. The walking distance, step count, walking speed, stride, heart rate, energy expenditure, and respiratory exchange ratio were measured.
Results: Walking distance, step count, walking speed, heart rate, and energy expenditure during walking were significantly higher in the gum trial than in the tablet trial. In participants aged ≥40 years, walking distance, walking speed, stride, heart rate, and energy expenditure during walking were significantly increased during the gum trial compared with those during the tablet trial.
Conclusion: The study findings demonstrated that gum chewing while walking increased walking distance and energy expenditure in both male and female individuals.

Introduction

Globally, the number of overweight and obese people has been increasing. As such, the World Health Organization (WHO) has stated that it is necessary to gain control of the global obesity epidemic.[1] Furthermore, the WHO has highlighted that many causes of overweight and obesity are preventable and reversible. However, no country has yet reversed the growth of this epidemic.[2] Overweight and obesity are major risk factors for a number of chronic diseases, including cardiovascular disease, metabolic disease, musculoskeletal disorders, and cancer.[2] Effective methods for the prevention and treatment of overweight and obesity are needed to influence the onset and progression of these associated diseases.

Gum chewing stimulates sympathetic nervous activity and increases heart rate and energy expenditure.[3–5] In addition, gum chewing for a total of 1 h (3 sessions of 20 min each) before and after consumption of a breakfast shake increases energy expenditure.[6] Furthermore, gum chewing for 15 min after consumption of a

* Corresponding author. Waseda University, Faculty of Sport Sciences, 2-579-15 Mikajima, Tokorozawa, Saitama, 359-1192, Japan.
E-mail addresses: y.hamada@kurenai.waseda.jp, y.hamada2@kurenai.waseda.jp (Y. Hamada), c-nagayama@moegi.waseda.jp (C. Nagayama), k-kashiwabara@toki.waseda.jp (K. Fujihira), y.tataka@ruri.waseda.jp (Y. Tataka), a.hiratsu@ruri.waseda.jp (A. Hiratsu), k.kamemoto@aoni.waseda.jp (K. Kamemoto), shimo_kanako@lotte.co.jp (K. Shimo), kanno_susumu@lotte.co.jp (S. Kanno), oosawa_kenji@lotte.co.jp (K. Osawa), m.miyashita@waseda.jp (M. Miyashita).

https://doi.org/10.1016/j.jesf.2021.04.001
1728-869X/

621-kcal meal promoted diet-induced thermogenesis.[7] Gum chewing also affects appetite and suppresses energy intake.[8,9] Collectively, these findings indicate that gum chewing may be an effective method of weight management. In addition, it is generally accepted that physical activity confers both physiological and psychological health benefits and reduces the risk of cardiovascular diseases and certain cancers.[10] To date, two studies[11,12] have investigated the effects of gum chewing while walking on physiological and physical functions. One study reported an increase in heart rate when participants chewed gum while walking compared with when participants did not chew gum while walking. Furthermore, this effect was particularly apparent in middle-aged and elderly male participants, in whom the walking distance, heart rate, and energy expenditure increased.[11] Another study demonstrated that gum chewing while walking increased energy expenditure, heart rate, step count, walking distance, and walking speed compared with walking without chewing gum.[12] However, these studies have methodological issues with regard to the assessment of energy expenditure (i.e., estimated from walking speed)[11] and a limited number of participants (15 participants in total).[12] Therefore, additional research is needed to elucidate the effects of gum chewing while walking on physiological and physical functions.

Thus, this study aimed to examine the effects of gum chewing while walking on walking distance and energy metabolism in male and female individuals of various ages. We tested the hypothesis that gum chewing while walking, compared with ingesting tablets while walking, would lead to increased walking distance and energy expenditure, particularly in middle-aged and older adults.

Methods

Participants

This study was approved by the Institutional Ethics Committee on Human Research (Approval number: 2019-015) and was conducted according to the Declaration of Helsinki. All participants gave written informed consent before participating in the study. This study was registered in advance with the University Hospital Medical Information Network Center (UMIN), a system for registering clinical trials (ID: UMIN000036534). A flow diagram of participants is shown in Fig. 1. This study enrolled 50 participants aged between 20 and 69 years and 5 male and 5 female participants enrolled in each 10-year age group. Fifty participants who gave informed consent and underwent screening were invited to complete two trials in a random order. The lead investigator enrolled participants to the study and randomly assigned the trial sequence in a counterbalanced manner using computer-generated random numbers to avoid order effects. Because of the nature of the study design, it was not possible to blind participants to the trial order allocation. The selection criteria for this study were as follows: aged between 20 and 69 years, body mass index (BMI) between 22 and 30 kg/m^2, and a habit of gum chewing (minimum once per week). Baseline physical characteristics of the participants are shown in Table 1.

Study design and protocol

A randomized, single-blind, controlled, cross-over design was employed in this study. Participants were not informed about the exact purpose or hypothesis of the present study to avoid possible results bias. Instead, the participants were simply told that the study was designed to examine the effects of food intake while walking on physical and physiological functions. Walking was selected as the mode of physical activity because walking is one of the most widely performed activities in Japan.[13] The provider of the test sample (i.e., gum or tablet) to the participants decided not to measure walking distance, and the measurers were masked to trials that the participants performed—since a double-blind test was not possible in the present study. Our intention with this practice was to ensure the execution of a single-blind test. Each participant underwent two trials, namely gum chewing while walking trial (gum trial) and tablet intake while walking trial (tablet trial), in a random order. The experiments were performed in our university's sports hall at a temperature of 29.1 °C ± 3.4 °C (mean ± standard deviation [SD]), with a relative humidity of 49.2% ± 9.4%.

A schematic representation of the study protocol is shown in Fig. 2. Participants fasted 4 h before arriving at the sports hall. On arrival, participants were asked to consume a 200-kcal energy bar (Calorie Mate, Otsuka Pharmaceutical Co., Ltd., Tokyo, Japan), and their body mass and height were measured. Thirty minutes after arriving at the sports hall, the participants performed a 10-min practice walking session to familiarize themselves with the protocol while wearing the main unit of the wearable K5 metabolic system (COSMED srl, Rome, Italy). Thereafter, the participants rested for 40 min in a chair. After resting, heart rate and metabolic data were recorded over a 10-min period while participants remained seated in a chair. Then, the participants walked at a natural pace for 15 min on a 98.04-m track while chewing two gum pellets at a self-selected pace (i.e., 1.5 g, 3 kcal per pellet; gum trial) or ingesting two tablet pellets (the tablet was designed to rapidly dissolve) containing the same ingredients with the exception of the gum base (tablet trial). After the first walking session, participants rested for 40 min in a chair, and resting heart rate and metabolic data were recorded over a 10-min period. Next, the participants completed the second trial by walking at a natural pace for 15 min while chewing either gum or table pellets (the opposite of their first trial pellet).

Calculations and analytic methods

Body mass was measured to the nearest 0.1 kg using a digital scale (Inner Scan 50, Tanita Corporation, Tokyo, Japan) and height was measured to the nearest 0.1 cm using a stadiometer (YS-OA, AS ONE Corporation, Osaka, Japan). BMI was calculated as weight in kilograms divided by the square of height in meters. Walking distance was measured as the distance walked in 15 min on a 98.04-m track. Participants walked the track counterclockwise at their own natural pace – only one participant walked the track at each time. Step count was measured using an accelerometer (Kenz Lifecorder EX, SUZUKEN Co., Ltd, Aichi, Japan). Walking speed was calculated based on walking distance and walking time (15 min). Stride was calculated based on walking distance and step count. A heart rate monitor (RCX 3, Polar Co., Kempele, Finland) was attached to the chest, and the heart rate was measured. Participants wore the main unit of the wearable K5 metabolic system (COSMED srl, Rome, Italy), which was connected to the face mask, on their back (device including battery weight, 900 g). The K5 system uses a galvanic fuel cell and a non-dispersive infrared sensor for the analysis of oxygen (O_2) and carbon dioxide (CO_2) in the inhaled and exhaled air and an optoelectronic reader with a high-performance turbine flowmeter to measure flow rate. The reader measures infrared light interruptions caused by the spinning blade inside the turbine. This study utilized a micro-dynamic mixing chamber measurement of gas exchange. The energy expenditure and respiratory exchange ratio data were obtained from the measured values using the wearable K5 metabolic system.

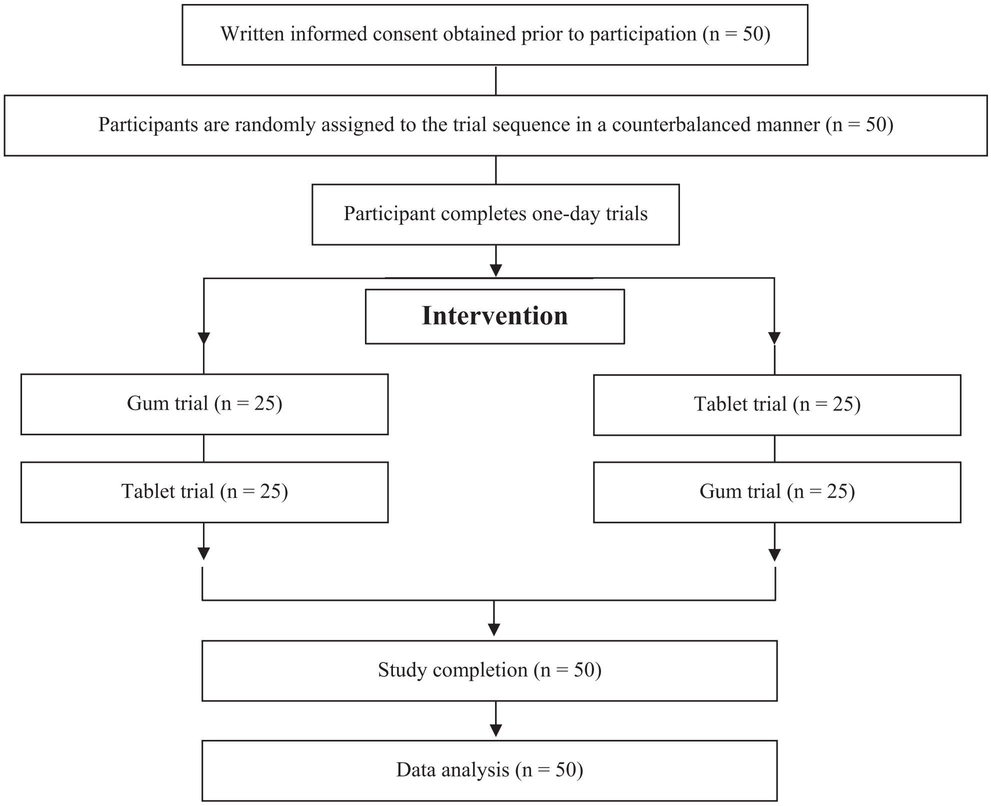

Fig. 1. Study recruitment and design.

Table 1
Characteristic of the participants.

	All (n = 50)		Young group (n = 20)		Middle-aged/elderly group (n = 30)	
	Male (n = 25)	Female (n = 25)	Male (n = 10)	Female (n = 10)	Male (n = 15)	Female (n = 15)
Age (years)	46 ± 15	44 ± 14	31 ± 6	29 ± 4	56 ± 9	54 ± 8
Height (m)	1.69 ± 0.05	1.57 ± 0.07	1.69 ± 0.05	1.59 ± 0.05	1.70 ± 0.06	1.55 ± 0.08
Body mass (kg)	73 ± 8	62 ± 9	73 ± 9	62 ± 9	73 ± 8	61 ± 9
BMI (kg/m^2)	25.4 ± 2.4	25.2 ± 2.7	25.5 ± 2.2	24.8 ± 2.9	25.4 ± 2.6	25.4 ± 2.6

All values are given as the mean ± SD. BMI: body mass index.

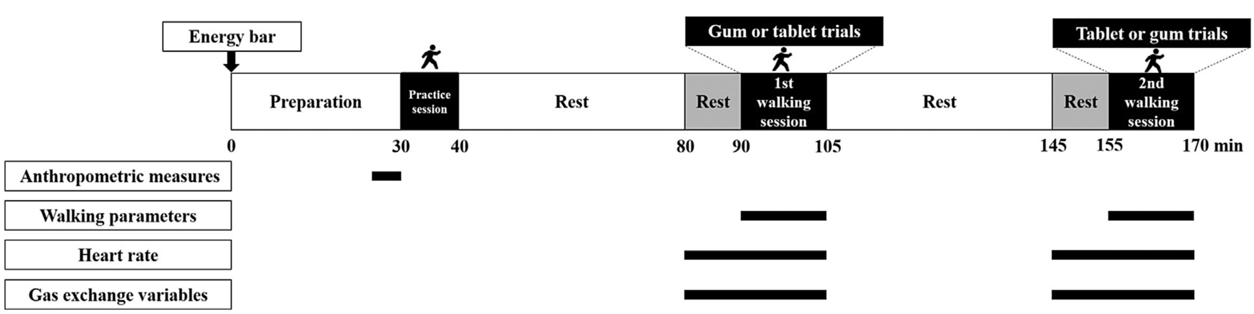

Fig. 2. A schematic representation of the study protocol.
Thirty minutes after arrival at the sports hall, participants performed a 10-min practice walking session. In the gum trial, participants walked at a natural pace for 15 min while chewing two gum pellets (1.5 g and 3 kcal per pellet), following a 50-min rest period. In the tablet trial, participants walked at a natural pace for 15 min after ingesting two tablet pellets containing the same ingredients with the exception of the gum base after a 50-min rest period. The heart rate, energy expenditure, and respiratory exchange ratio were measured at rest for 10 min before the first and second walking sessions. The walking distance, step count, walking speed, stride, heart rate, energy expenditure, and respiratory exchange ratio were measured for 15 min during the first and second walking sessions.

Statistical analysis

In the present study, the primary outcome was energy expenditure during walking. The sample size was estimated using G*Power 3.1,[14] and was based on the data from a previous study that investigated the effects of gum chewing while walking on energy expenditure in young and middle-aged men and women.[12] The sample size was calculated to detect an effect size of 0.836 using a paired *t*-test for comparison between trials. For two trials with an alpha level set at 0.05, an estimated total sample size of 21 would provide 95% power to detect between-trial differences. Based on these calculations, we recruited 50 participants to account for potential inter-individual differences in energy expenditure considering the wide range of age groups. A paired *t*-test was performed to compare each outcome variable between the gum and tablet trials. Stepwise regression analysis was used to estimate which factors independently contribute to energy expenditure during walking; step count, walking distance, walking speed, and stride were independent variables, and energy expenditure during walking was the dependent variable (criteria for probability of F: entry 0.05, removal 0.10). Furthermore, the effect of the characteristics of the participants on variables that affected energy expenditure was analyzed using stepwise regression analysis. All statistical analysis performed using the SPSS Statistics version 25 statistical analysis software (IBM Corporation, Armonk NY, USA) and jamovi 1.6.15, and a p-value <0.05 was deemed to be statistically significant. All values are expressed as mean ± SD. Stratified analyses were also performed with respect to differences in sex and age groups (the "young" group was defined as participants aged 20–39 years, and the "middle-aged/elderly" group was defined as participants aged 40–69 years).[11] The 95% confidence intervals (95% CI) for the mean absolute pairwise differences between the two trials were calculated using t-distribution and degrees of freedom ($n-1$). Effect sizes (ES; Cohen's d) were calculated to describe the magnitude of the difference between trials. An effect size of 0.2 was considered the minimal clinically important difference for all outcome measures, 0.5 was considered moderate, and 0.8 was considered large.[15]

Results

For all participants, regardless of age or sex, significant differences between the gum and tablet trials with respect to walking distance (mean difference [95% CI] and ES [95% CI]; 16.5 [0.464, 32.6] and 0.292 [0.008, 0.574]), step count (11.0 [0.938, 21.0] and 0.321 [0.026, 0.613]), walking speed (1.20 [0.130, 2.27] and 0.319 [0.033, 0.602]), heart rate (2.15 [1.01, 3.29] and 0.535 [0.236, 0.829]), and energy expenditure (3.08 [0.994, 5.16] and 0.420 [0.129, 0.707]) during walking were evaluated. These values were significantly higher in the gum trial than in the tablet trial (Table 2).

Stratified analysis with respect to participant sex revealed that in male participants, the heart rate (mean difference [95% CI] and ES [95% CI]; 1.64 [0.388, 2.90] and 0.540 [0.115, 0.956]) and energy expenditure (2.93 [0.658, 5.19] and 0.532 [0.108, 0.947]) during walking were significantly higher in the gum trial than in the tablet trial (Table 2). In female participants, the heart rate (mean difference [95% CI] and ES [95% CI]; 2.65 [0.666, 4.64] and 0.551 [0.125, 0.968]) during walking was significantly higher in the gum trial than in the tablet trial.

Stratified analysis of the results obtained from the young and middle-aged/older participant groups revealed that in the young participant group, the walking distance, walking speed, stride, heart rate, and energy expenditure during walking were not significantly different between the gum and tablet trials (Table 2), whereas in the middle-aged/older participant group, significant differences were observed (mean difference [95% CI] and ES [95% CI]; walking distance, 25.9 [3.82, 47.9] and 0.438 [0.060, 0.810]; walking speed, 1.80 [0.302, 3.30] and 0.449 [0.069, 0.821]; stride, 1.12 [0.013, 2.23] and 0.400 [0.004, 0.789]; heart rate, 2.74 [1.17, 4.31] and 0.651 [0.251, 1.04]; and energy expenditure, 4.66 [1.59, 7.73] and 0.567 [0.177, 0.950]). These values were significantly higher in the gum trial than in the tablet trial (Table 2).

To assess factors that independently contribute to energy expenditure during walking, stepwise regression analysis was performed. Walking speed was the most powerful predictor of energy expenditure during walking ($R = 0.583$, adjusted $R^2 = 0.333$, β coefficient = 0.583, variance inflation factor = 1.000). Walking distance, step count, and stride were not predictive of energy expenditure during walking as calculated using multiple regression analysis. The heart rate during walking (β coefficient = 0.476, variance inflation factor = 1.160) and sex (β coefficient = −0.383, variance inflation factor = 1.160) contributed to the walking speed ($R = 0.487$, adjusted $R^2 = 0.222$).

Discussion

The present study revealed that gum chewing while walking increased the walking distance, step count, walking speed, heart rate, and energy expenditure during walking. The findings also showed that gum chewing while walking increased the walking distance, walking speed, stride, heart rate, and energy expenditure during walking in middle-aged/elderly participants.

The findings of the present study support the results of our previous studies that found gum chewing while walking increased physical and physiological functions.[11,12] Our previous study demonstrated that in a total of 46 male and female participants

Table 2
Physical and physiological data, all and stratified by sex and age, in the gum and tablet trials.

	All (n = 50)		Male (n = 25)		Female (n = 25)		Young group (n = 20)		Middle-aged/elderly group (n = 30)	
	Gum	Tablet	Gum	Tablet	Gum	Tablet	Gum	Tablet	Gum	Tablet
Walking distance (m)	1138 ± 120*	1121 ± 116	1158 ± 126	1148 ± 125	1117 ± 112	1094 ± 102	1105 ± 112	1103 ± 119	1159 ± 121*	1133 ± 114
Step count (steps)	1746 ± 108*	1735 ± 112	1710 ± 116	1702 ± 128	1781 ± 89	1768 ± 87	1700 ± 106	1684 ± 106	1781 ± 98	1773 ± 103
Walking speed (m/min)	75.9 ± 8.0*	74.7 ± 7.7	77.3 ± 8.4	76.5 ± 8.2	74.5 ± 7.5	72.9 ± 6.8	73.8 ± 7.5	73.5 ± 7.7	77.3 ± 8.1*	75.5 ± 7.6
Stride (cm/step)	65.3 ± 6.8	64.8 ± 6.5	67.9 ± 6.4	67.7 ± 5.7	62.7 ± 6.3	62.0 ± 6.2	65.1 ± 6.6	65.5 ± 6.2	65.4 ± 7.2*	64.2 ± 6.8
Heart rate (bpm)										
Resting	76 ± 12	76 ± 12	75 ± 13	76 ± 13	76 ± 11	77 ± 11	73 ± 11	75 ± 11	77 ± 13	77 ± 12
Walking	104 ± 16*	102 ± 15	98 ± 15*	97 ± 15	110 ± 15*	107 ± 14	100 ± 15	99 ± 14	107 ± 16*	104 ± 15
Respiratory exchange ratio										
Resting (10 min)	0.82 ± 0.06	0.82 ± 0.07	0.84 ± 0.06	0.83 ± 0.06	0.81 ± 0.07	0.80 ± 0.06	0.85 ± 0.06	0.84 ± 0.07	0.81 ± 0.06	0.80 ± 0.06
Walking (15 min)	0.85 ± 0.06	0.85 ± 0.06	0.86 ± 0.05	0.87 ± 0.06	0.85 ± 0.07	0.84 ± 0.06	0.87 ± 0.07	0.87 ± 0.07	0.84 ± 0.05	0.84 ± 0.05
Energy expenditure (kcal)										
Resting (10 min)	13.0 ± 2.6	12.9 ± 2.5	13.4 ± 2.7	13.5 ± 2.6	12.5 ± 2.4	12.3 ± 2.2	12.5 ± 2.8	12.9 ± 2.2	13.3 ± 2.5	12.9 ± 2.7
Walking (15 min)	63.4 ± 15.2*	60.3 ± 13.5	63.7 ± 14.9*	60.8 ± 14.2	63.0 ± 15.9	59.8 ± 12.9	56.6 ± 10.2	55.9 ± 9.3	67.9 ± 16.5*	63.2 ± 15.1

All values are given as the mean ± SD. *$p < 0.05$, gum trial vs. tablet trial. bpm: beats per minute.

aged 21–69 years, gum chewing (two pieces) while walking for 15 min increased heart rate.[11] In the present study, we found that besides increasing the heart rate during walking, walking distance, step count, and walking speed were increased in the gum trial compared with those in the tablet trial. In addition, energy expenditure during walking was increased. In a previous study,[11] energy expenditure was calculated based on walking speed using the American College of Sports Medicine's formula.[16] Thus, the findings of this study support and confirm the findings of our previous study.[11] Our previous study found that gum chewing increased walking heart rate only.[11] In contrast, the present study found that gum chewing increased the walking distance, step count, walking speed, heart rate, and energy expenditure during walking. Regarding the difference between the results of the two studies, it is possible that, in this study, many measured parameters increased by gum chewing while walking in the middle-aged and older participants. Thus, data from the middle-aged and older participants may have contributed to the overall results. Another study by our group that included 15 male and female individuals also demonstrated that walking distance, step count, walking speed, walking heart rate, and energy expenditure during walking were higher during the gum trial (two pieces) than during the tablet trial.[12] However, our previous study[12] was limited by the small number of participants. The present study is an extension of our previous study[12] and demonstrates that in a relatively large sample, gum chewing increases walking distance, heart rate, and energy expenditure during walking.

Energy expenditure increased by gum chewing during walking in the present study. A previous study in which participants chewed 1.9 g of gum for 20 min while at rest reported that energy expenditure increased by 5.1% due to gum chewing.[6] In the present study, chewing two gum pellets (3 g) for 15 min during a walking session increased the energy expenditure by 5.1%. Thus, the increment of energy expenditure by gum chewing during walking in the present study was consistent with the increment of energy expenditure by gum chewing at rest in the previous study.

The mechanism by which gum chewing while walking increases these physical functions, including walking distance, step count, walking speed and stride, is unknown. One possible mechanism is cardiac-locomotor synchronization (CLS) or cardiac-locomotor coupling, through which the locomotor activity rhythm synchronizes heart rhythm.[17] In the present study, the findings of the stepwise regression analysis revealed that walking speed contributed to energy expenditure and heart rate during walking, and sex contributed to walking speed. Increased heart rate during walking caused by gum chewing could have generated CLS, which then involved physical function, leading to increased walking distance, step count, and walking speed. Chewing is one of the locomotor rhythms. Therefore, the tempo of gum chewing could have affected the walking tempo in the present study, and this increased walking tempo by gum chewing could have resulted in increments in walking distance, step count, and walking speed. A recent study demonstrated a strong association between chewing and walking in young healthy adults and healthy older adults.[18] In addition, CLS is more likely to occur in older adults than in young adults.[19] The greatest difference in the heart rate between the gum and tablet trials were observed in middle-aged and elderly participants compared with young participants in the present study. It is also worth noting that the results of the present study were influenced by sex. This confirms the findings of our previous study that had a similar experimental design.[11] A previous study indicated less masticatory muscle activity in female individuals compared with that in male individuals, and less masticatory muscle activity in middle-aged and elderly female individuals compared with that in young female individuals.[20] It is unclear that how these sex differences in masticatory activity influence CLS. Thus, further research is required to develop a mechanistic understanding of CLS and to elucidate the effect of CLS on physical functions.

One limitation of the present study is the lack of quantitative or qualitative measurements of chewing while walking. In future studies, it would be interesting to measure these parameters as the additional data (rate of chewing and the intensity of chewing) and these data could help us to understand and provide more holistic insights into the role of gum chewing while walking on physical and physiological functions.

Conclusion

The present study demonstrated that gum chewing while walking increased walking distance and energy expenditure in both male and female individuals.

Author contributions

Y.H. designed the study, supervised the data collection, performed the data analysis and interpretation, and wrote the manuscript. C.N., K.F., Y.T., A.H., and K.K. assisted the data collection and/or interpretations. K.S., S.K., and K.O. designed the study. M.M. conceived the study, designed the study, obtained the funding and took the lead in writing the manuscript. All authors approved the final version of the manuscript.

Declaration of competing interest

K.S., S.K. and K.O. are employees of Lotte Co., Ltd. and were not involved in the data acquisition, statistical analysis and interpretation of the results - K.S., S.K. and K.O. were involved in the study design, and the decision to submit the manuscript for publication. M.M. has no professional relationships with the company involved in this study. M.M. received a research grant from Lotte Co., Ltd. For the remaining authors none were declared conflicts of interest.

References

1. World Health Organization. Activities; Controlling the global obesity epidemic. https://www.who.int/activities/controlling-the-global-obesity-epidemic. Accessed November 17, 2020.
2. World Health Organization. Health topics; Obesity. https://www.who.int/health-topics/obesity. Accessed November 17, 2020.
3. Levine J, Baukol P, Pavlidis I. The energy expended in chewing gum. *N Engl J Med*. 1999;341:2100.
4. Farella M, Bakke M, Michelotti A, et al. Cardiovascular responses in humans to experimental chewing of gums of different consistencies. *Arch Oral Biol*. 1999;44:835–842.
5. Hasegawa Y, Sakagami J, Ono T, et al. Circulatory response and autonomic nervous activity during gum chewing. *Eur J Oral Sci*. 2009;117:470–473.
6. Kresge DL, Melanson K. Chewing gum increases energy expenditure before and after controlled breakfasts. *Appl Physiol Nutr Metabol*. 2015;40:401–406.
7. Hamada Y, Miyaji A, Hayashi N. Effect of postprandial gum chewing on diet-induced thermogenesis. *Obesity*. 2016;24:878–885.
8. Hetherington MM, Boyland E. Short-term effects of chewing gum on snack intake and appetite. *Appetite*. 2007;48:397–401.
9. Park E, Edirisinghe I, Inui T, et al. Short-term effects of chewing gum on satiety and afternoon snack intake in healthy weight and obese women. *Physiol Behav*. 2016;159:64–71.
10. World Health Organization. Health topics; Physical activity. https://www.who.int/health-topics/physical-activity. Accessed November 17, 2020.
11. Hamada Y, Yanaoka T, Kashiwabara K, et al. The effects of gum chewing while walking on physical and physiological functions. *J Phys Ther Sci*. 2018;30:625–629.
12. Kanno S, Shimo K, Ando T, et al. Gum chewing while walking increases fat oxidation and energy expenditure. *J Phys Ther Sci*. 2019;31:435–439.
13. Japan Sports Agency. Public opinion survey on sports implementation status (survey in November-December 2013) https://www.mext.go.jp/sports/content/20200507-spt_kensport01-0000070034_8.pdf. Accessed November 17, 2020 (in Japanese).
14. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res*

Methods. 2007;39:175–191.
15. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. Lawrence Erlbaum Associates; 1988.
16. Glass S, Gregory B. *ACSM's Metabolic Calculations Handbook*. Baltimore: Lippincott Williams & Wilkins; 2007:22.
17. Takeuchi S, Nishida Y. Possible application of cardiac-locomotor synchronization in physical therapy. *Rigakuryoho Kagaku*. 2009;24:777–784 (in Japanese).
18. Samulski B, Prebor J, Armitano C, Morrison S. Coupling of motor oscillators - what really happens when you chew gum and walk? *Neurosci Lett*. 2019;698: 90–96.
19. Novak V, Hu K, Vyas M, et al. Cardiolocomotor coupling in young and elderly people. *J Gerontol A Biol Sci Med Sci*. 2007;62:86–92.
20. Furuya M, Yoshida M, Nokubi T, et al. Evaluation of masticatory function by using the testing gumi-jelly. Influence of age and sex on dentate subjects. *J Jpn Prosthodont Soc*. 1994;38:89–97 (in Japanese).