ACES Arquivos de Ciências do Esporte

Original article

O uso de smartphones altera a percepção de esforço e biomecânica, mas não de parâmetros fisiológicos durante a marcha em esteira: um estudo piloto

Smartphone use changes rating of perceived exertion and biomechanics but not physiological parameters during gait on treadmill: a pilot study

Ricardo B. Viana[1], Cleber L.C. Godoy[1], Paulo Gentil[1], Douglas A.T Santos[2], Mario H. Campos[1], Carlos A. Vieira[1], Rodrigo L. Vancini[3], Marília S. Andrade[4] and Claudio A.B. de Lira[1,*]

[1] Laboratório de Avaliação do Movimento Humano, Faculdade de Educação Física e Dança, Universidade Federal de Goiás, Brazil.
[2] Colegiado de Educação Física, Universidade do Estado da Bahia, Brazil.
[3] Centro de Educação Física e Desposto, Universidade Federal do Espirito Santo, Brazil.
[4] Departamento de Fisiologia, Universidade Federal de São Paulo, Brazil.

[*] Correspondence: andre.claudio@gmail.com

Citação: Viana, R.B.; Godoy, C.L.C.; Santos, D.A.T.; Campos, M.H.; Vieira, C.A.; Vancini, R.L.; Andrade, M.S.; Lira, C.A.B. Smartphone use changes rating of perceived exertion and biomechanics but not physiological parameters during gait on treadmill: a pilot study. Arq Cien do Esp **2020**, *8*. https://doi.org/10.29327/2633896

Recebido: junho/2020
Aceito: setembro/2020

Resumo: *Introdução*: O uso de celulares durante a caminhada altera parâmetros biomecânicos, porém pouco se sabe sobre os ajustes fisiológicos e alterações na percepção subjetiva de esforço. *Objetivos*: Avaliar a percepção subjetiva de esforço, respostas biomecânicas e fisiológicas de indivíduos adultos durante caminhada em esteira digitando no celular. *Métodos*: Trinta homens saudáveis realizaram em ordem aleatória cinco minutos de caminhada em esteira enquanto digitavam em um celular (TYP) ou cinco minutos em sessão controle (caminhada sem digitar no celular [CON]). Foram avaliadas a frequência cardíaca, pressão arterial sistólica, pressão arterial diastólica, percepção subjetiva de esforço, frequência da passada e comprimento da passada. *Resultados*: A pressão arterial sistólica foi similar após CON e TYP, porém foi maior do que no repouso. Não foi encontrada nenhuma diferença significativa entre a pressão arterial diastólica no repouso, após CON e após TYP. A frequência cardíaca após CON e TYP foi 29,7% e 39,2% maior do que no repouso, respectivamente, porém não foi encontrada diferença significante entre as sessões. A percepção subjetiva de esforço após TYP foi maior do que após CON. O comprimento da passada durante TYP foi menor do que durante CON. A frequência da passada durante TYP foi maior do que durante CON. *Conclusão*: Cinco minutos da sessão TYP aumentaram a percepção subjetiva de esforço e alteraram parâmetros biomecânicos em homens saudáveis quando comparados a sessão CON. Contudo, os parâmetros fisiológicos mensurados não se alteraram.

Palavras-chave: celular; caminhada; marcha; respostas fisiológicas; respostas biomecânicas

Abstract: *Introduction*: The use of smartphones during walking changes biomechanical parameters, but less is known about rating of perceived exertion and physiological adjustments to walking activity. *Objective*: To evaluate rating of perceived exertion, biomechanical and physiological responses during gait on treadmill while typing on a smartphone. *Methods*: Thirty men performed five minutes of walking on a treadmill while typing on a smartphone (TYP) or during control conditions (walk without type on a smartphone, [CON]) in random order. Heart rate, systolic blood pressure, diastolic blood pressure, rating of perceived of exertion, stride frequency and stride length were evaluated. *Results*: Systolic blood pressure after CON and TYP was significantly higher than at rest, but there was no significant difference between conditions. There was no significant difference between diastolic blood pressure at rest, after CON, and after TYP. Heart rate after CON and TYP was 29.7% and 39.2% higher than at rest, respectively, but there was no significant difference between conditions. Rating of perceived of exertion after TYP was greater than after CON. Stride length during TYP was shorter than during CON. *Conclusion*: In conclusion, five minutes of walking while use smartphone changed rating of perceived exertion and biomechanics but not physiological parameters during gait.

Keywords: physical activity; sedentary; health; behavior change

1. Introduction

The use of smartphones has become common in modern society[1]. Over half the population in developed countries relies on them daily, and this rate is expected to reach 80% by 2020[1]. In some developed countries (e.g., Switzerland), nearly all adolescents (98%) own a mobile phone, most of which (97%) are smartphones[2]. In developing countries, such as Brazil, 77.9% of people aged 10 years or more have at least one mobile phone[3]. In addition, it is estimated that 73.6% of Brazilians use their cell phones to access the internet and communicate, whether through voice or text messaging applications[3].

In the daily routine, use of mobile phones while performing other activities such as walking[4,5] or driving is common[6,7]. Previous studies have shown that the risk of accidents affecting pedestrians and drivers is higher while a phone is being used[6,7] and that dual-task walking changes the characteristics of the stride (a complete cycle of two consecutive steps), increasing the risk of falls[4].

In addition, the use of a smartphone during walking can change biomechanical parameters[8,9] such as reducing gait velocity[5]. Moreover, in most pathologic conditions, steps tend to be even shorter and to present a higher cadence (steps/minute) than is physiologically necessary for the lower speed that is adopted[10]. In fact, previous studies showed there is a relationship between in biomechanical and physiological variables during gait in healthy and clinical populations. For example, children are less efficient walkers than adults, because they have a faster cadence to compensate for a shortened stride length; as consequence, they present higher oxygen cost (in ml/kg/meter)[11,12] and higher heart rate than adults[12]. In clinical population, when walking speed was held constant (80 m/min), the oxygen uptake increased 23% when subjects walked with the knee immobilized[13]. Restricting knee extension cause rise in the oxygen uptake during walking[11]. In athletes, biomechanical variables can be used to discriminate between recreational and well-trained runners at various submaximal speeds[14]. Therefore, it is reasonable to assume that the use of a smartphone during walking can change physiological parameters, including cardiovascular variables.

However, to best of our knowledge, no studies have investigated the possible changes in physiological responses when walking while using a mobile phone. Among physiological variables, those related to the cardiovascular system, such as heart rate and blood pressure, are important measures that reflect cardiovascular responses to exercise. In addition, the assessment of rating of perceived of exertion (RPE) is also an easy and low-cost tool for providing information about exercise intensity[15,16].

Considering that the use of smartphones is highly prevalent in modern society and that it has previously been shown that the use of such devices during gait changes biomechanical parameters, studies that investigate RPE and physiological measures are warranted. Thus, the main aim of the current study was to evaluate the RPE and physiological measures during walking of healthy adults while typing on a smartphone. The secondary aim was to evaluate biomechanical variables in order to confirm results from previous studies. It is hypothesized that RPE, physiological and biomechanical measures will change during gait with the use of a smartphone compared to a walking control condition.

Methods

Participants

Thirty healthy male adults (a convenience sample) were recruited among students from the Faculty of Physical Education and Dance of the Federal University of Goiás (Goiânia, Brazil). Participants were recruited through social media and direct contact. The age and anthropometrical characteristics of the participants are presented in Table 1. Inclusion criteria were: (i) being a user of a smartphone and the WhatsApp® messaging application, (ii) being a male aged between 18 and 30 years and (iii) be familiarized with walking on a treadmill. The exclusion criteria were: (i) contraindication to physical activity screened using the Physical Activity Readiness Questionnaire (PAR-Q)[17] and (ii) to present neurological, cognitive and orthopedic. All participants were informed of the intent, experimental procedures, benefits and risks of the study, and an informed consent was obtained from all individual participants. All experimental procedures were approved by the University Human Research Ethics Committee (April 25, 2017, no. 1.459.010) and conformed to the principles outlined in the Declaration of Helsinki. There were no medical complications during experimental procedure and none participants withdrew their consent.

Table 1. Characteristics of the participants (n = 30).

Variables	Mean ± standard deviation	Minimum–maximum
Age (years)	23.1 ± 2.9	19.3–29.2
Height (m)	1.78 ± 0.06	1.68–1.92
Body mass (kg)	74.4 ± 9.8	56.8–97.5
Body mass index (kg/m^2)	23.5 ± 2.4	17.5–27.9

Study design

This was a cross-sectional crossover study. The study involved two tests performed on the same day in a randomized order. The tests lasted five minutes and consisted of a normal walk (without type on a smartphone, [CON]) and a walk while typing into a messaging application (WhatsApp®, USA) on a smartphone (TYP) (Figure 1). The participants used their own smartphones because they were familiar with the devices. Although in the CON conditions, the participants did not text on their smartphone, they remained with the phone in one hand. Each test lasted five minutes because this is sufficient for physiological variables to attain a steady state in most healthy people [18]. Immediately after each test, systolic and diastolic blood pressure (SBP and DBP) were measured with the participants seated, and RPE was monitored. Heart rate and stride length were monitored at all times in both tests. Recovery time between tests was set at a minimum of 20 minutes, since that period allows physiological variables to return to resting values[19]. During this period the participants remained seated quiet in a chair. Participants were directed to eat a standardized meal, not to participate in any strenuous exercise, and not to consume any stimulant or alcohol in the 24 hours preceding the testing session. The temperature and relative humidity in the testing laboratory ranged from 21 to 23 °C and 55% to 65%, respectively.

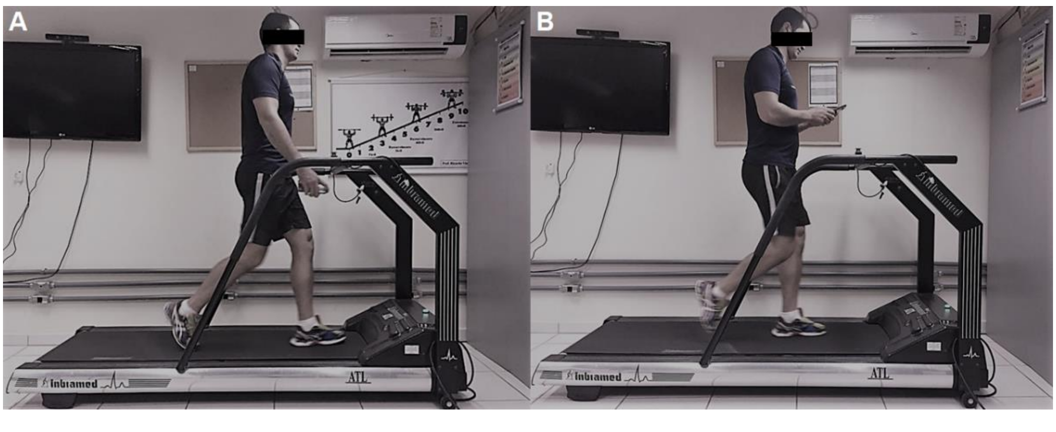

Figure 1. Walking without typing (A) and while typing on a smartphone (B).

Walking tests

Both tests were performed on a motorized treadmill (ATL, Inbramed, Brazil) with 0% slope and at 5 km/h. After one of the two tests, the participant remained seated for 20 minutes for the heart rate to return to the pre-test value. After this period, the participant performed the other test. We chose a walking modality because it is the main form of human locomotion and is frequent in activities of daily life; 5 km/h was used because it is the average walking speed used by most healthy adults[20] and because some studies have compared comprehensively self-selected pace treadmill walking with fixed speed treadmill walking and showed that gait patterns were comparable between self-selected pace (~5km/h) and fixed speed treadmill walking (~5km/h)[21,22].

Assessment of physiological and perceptual measures

Heart rate responses were evaluated using a heart rate monitor (model RS800CX, Polar, Finland) coupled at the height of the xiphoid process of the participants. SBP and DBP were measured before and immediately after each test using a validated automatic digital blood pressure monitor (OMRON, HEM-7113, China). The blood pressure monitor was used according to the manufacturer's instructions. Participants' RPE was recorded immediately after each test using the Borg scale of 6–20 points[15]. Borg scale is composed by a quantitative scale ranging from 6 to 20 points, and also is composed by a qualitative scale ranging from a "very, very light" to "very, very hard" exercise intensity[15]. Moreover, Borg's RPE is an affordable, practical and valid tool for monitoring and prescribing exercise intensity, independent of gender, age, exercise modality, and physical activity level[23].

Assessment of biomechanical measures

The biomechanical variables measured were length and frequency of stride. Both walking tests (CON and TYP) were recorded using a digital camera (ST77, Samsung, Brazil) attached to a tripod and positioned two meters away on the right side of the treadmill. After that, the number of strides was counted by a trained examiner, and the average stride length of the participant during each test was calculated using the following equation: stride length (m) = velocity (m/s)/frequency of strides [18].

Smartphone and instant messaging service for smartphones

During TYP, an excerpt from one of Paulo Coelho's books was dictated (available in the supplementary material). The participant was instructed to type on the smartphone using two hands in order to enter as many words as possible through the messaging application. The participant was not allowed to use Swype mode to type on the smartphone's keyboard.2.1. Smartphone and instant messaging service for smartphones.

Statistical analysis

Data are presented as number and percentage for categorical variables; continuous data are expressed as mean ± standard deviation. According to the Shapiro–Wilk test, all variables presented a normal distribution. Student's *t*-test was used to compare the RPE after CON and TYP, and stride length and stride frequency during CON and TYP. Repeated-measures ANOVA was used to compare physiological variables (heart rate, SBP and DBP) at rest, after CON and TYP. Bonferroni post hoc testing was used where significance was indicated. In addition, carryover tests were performed for all variables to provide information about the effect of test order (CON vs. TYP or TYP vs. CON). *Pearson's* correlation coefficient was used to determine correlations between RPE and heart rate. Correlations below 0.49 were described as "poor", from 0.50 to 0.69 as "moderate," and 0.70 to 0.89 as "high," and from 0.9 and above as "very high"[24]. Cohen's *d* effect size for differences between CON and TYP conditions were calculated using the following formula: $Cohen's\ d = MD/(SD_{MD}/\sqrt{2\ x\ (1-r)})$. Where, MD, SD_{MD} and r represents the mean difference (TYP value – CON value), standard deviation of mean difference, and the coefficient of correlation, respectively. The magnitude of the Cohens' d effect size was classified as "trivial" (d < 0.2), "small" (0.2 ≤ d < 0.5)", "medium" (0.5 ≤ d < 0.8), and "large" (d ≥ 0.8)[25]. Statistical Package for the Social Sciences (SPSS) version 23 (IBM Corp., USA) was used for statistical analysis, and a significance level of .05 was set for all statistical tests.

3. Results

Physiological and perceptual measures

Examination of SBP indicated a significant difference (F [2,58] = 9.130; $p < .001$) for the three conditions (rest, after CON and after TYP). SBP evaluated after CON and TYP was 4.8% (**Δ**: 2 ± 9 mmHg; $p = .007$; d = 0.60) and 5.6% (**Δ**: 1 ± 7 mmHg; $p = .001$; d = 0.74) higher than at rest conditions, respectively. However, no significant difference in SBP ($p > .05$; d = -0.10) was found between after CON and TYP (Table 2). Examination of DBP indicated a non-significant difference between conditions (F [2,58] = 1.068; $p = .350$) at rest and after CON and TYP (Table 2).

Table 2. Physiological, perceptual and biomechanical responses to CON and TYP (n = 30).

Variables	Rest	CON	TYP	p^a	Cohen's d
SBP (mmHg)	125 ± 10	131 ± 11*	132 ± 13*	1.000	-0.10 [trivial]
DBP (mmHg)	67 ± 7	69 ± 9	68 ± 8	1.000	0.12 [trivial]
Heart rate (bpm)	74 ± 14	96 ± 21*	103 ± 13*	.191	-0.35 [small]
RPE (6–20)	N/A	8 ± 1	9 ± 2	<.001	1.27 [large]
Stride length (m)	N/A	1.46 ± 0.06	1.45 ± 0.07	.036	-0.40 [small]
Stride frequency (strides/minute)	N/A	57.25 ± 2.36	57.69 ± 2.57	.026	0.43 [small]

Examination of heart rate for the three conditions (rest, after CON and after TYP) indicated a significant difference (F [2,58] = 55.817; $p < .001$). Heart rate after CON and TYP was 29.7% (**Δ**: 23 ± 19 bpm; $p < .001$; d = 1.17) and 39.2% higher (**Δ**: 29 ± 7 bpm; $p < .001$; d = 3.98) than heart rate in rest conditions. However, heart rate during TYP was similar compared to CON (**Δ**: -6 ± 18 bpm; $p = .191$; d = -0.35). In addition, TYP resulted in a significantly higher RPE (**Δ**: 1.7 ± 1.3; $p < .001$; d = 0.63) as compared with CON (Table 2). There was evidence of carryover effect of the session order to the DBP ($p = .016$) but not to the SBP ($p = .283$), heart rate ($p = .301$), and RPE ($p = .195$).

There was a poor positive correlation between RPE and heart rate during TYP (r = 0.48; $p =.008$) but not during CON condition (r = 0.26; $p = .163$).

Biomechanical measures

Examination of stride length revealed that stride length during TYP was ~1% shorter than during CON (**Δ**: -0.01 ± 0.03 m; $p = .036$; d = -0.40), whereas stride frequency was ~1% higher in TYP than during CON (**Δ**: 0.44 ± 1.02 strides/minute; $p = .026$; d = 0.43) (Table 2). There was no evidence of carryover effect of the session order to the stride length (p = 0.730) and stride frequency (p = 0.890).

4. Discussion

This study analyzed the RPE, physiological and biomechanical responses during walking while typing on a smartphone. Our hypothesis was that RPE, physiological and biomechanical measures would suffer alterations with the use of a smartphone compared to a walking control condition. Our results partially confirmed our initial hypothesis, since we found a higher RPE in TYP condition when compared to CON condition. We also confirm the findings from previous studies with regard to biomechanical changes while dual-task walking. However, heart rate, SBP and DBP were similar between TYP and CON conditions.

Previous studies have already demonstrated that biomechanical measures are influenced by walking while texting. Lamberg and Muratori[26] reported that walking while typing on a smartphone decreased velocity by 33% and increased lateral deviation by 61%. Parr et al.[5] found a reduction of 16% in gait velocity during typing on a smartphone. Demura and Uchiyama[27] showed a 17% decrease in gait velocity when able-bodied young adults used the e-mail function on a cellular phone. Hollman et al.[28] reported an average decrease in gait velocity of 12% for individuals while spelling a five-letter word backward. Harshish et al.[29] found reductions of 2 ± 0.2 cm and 1 ± 0.2 cm in the single-step vertical heel clearance during stair descent and ascent, respectively. In addition, previous studies have shown the association between cognitive performance/abilities and gait characteristics[30,31]. Altogether, it is clear that dual-task walking (including mobile phone use) changes biomechanical variables related to gait. Different from other studies, we opted to keep speed constant in order to analyze biomechanical variables independently of velocity changes. By doing this, our findings on biomechanical variations confirmed results found in previous studies, since we found that stride frequency and length were influenced (small changes) during gait using a smartphone.

On the other hand, Magnani et al.[32] verified the effects of attentional dual tasks performed by 20 young people under four conditions: while using a cell phone during a 4-minute walk at 4 km/h on a treadmill looking forward at a fixed target 2.5 m away, talking on a cell phone with unilateral handling, texting messages on a cell phone with unilateral handling, and looking forward at the aforementioned target while listening to music without handling the phone. The authors did not find a significant difference in step length between any conditions. In the present study, participants walked at a greater velocity (5 km/h), which may explain the small changes found in the biomechanical variables investigated. Pizzamiglio et al.[33] analyzed stride length and frequency and walking velocity of 18 individuals (7 men and 11 women), and found a reduction in walking speed due to increased stride frequency rather than length. One important difference in our study is that we collected data using a motorized treadmill; therefore, the velocity remained constant independent of conditions (walking while texting or not), which increased stride frequency and consequently may have reduced the time per step, providing less time for a reaction to a possible perturbation.

A possible explanation for our results is that arm swing helps stabilize the trunk and control lateral stability of the body during walk, thus reducing the metabolic cost [34]. During walking while texting, arm swing is impaired; therefore, it was expected that TYP condition could provide perturbations in the movement pattern. Altogether, the cognitive requirement of typing on a cell phone and non-movement of the arms may have been the factors responsible for the reduction in stride length and increased stride frequency.

Another relevant point of the present study is that, to the best of our knowledge, no previous study had assessed RPE, physiological and biomechanical variables when the concomitant task was texting on a smartphone. Kodesh and Kizony[35] conducted a study in which 25 young adults (14 men and 11 women) performed an experimental protocol which included three conditions, each with and without performing a cognitive secondary task (solving puzzles), for a total of six tasks. The three conditions were: rest (sitting), walking over ground at a comfortable self-selected speed, and walking on a treadmill at a fast speed. The results showed that there were no significant differences in heart rate and oxygen uptake between walking and walking while solving puzzles. These results agree with the results of the present study, in which heart rate was similar between TYP and CON conditions. In thin sense, although the participants needed to pay attention to the text being dictated and then type the text into the smartphone, and the participants needed to look at the cell phone and not forward, which changes the normal movements of the trunk and head[36], it was not sufficient to increase participants' heart rate.

Another physiological variable evaluated was blood pressure. We did not find a significant difference in blood pressure between CON and TYP conditions. The absence of difference in blood pressure between the two conditions can be explained because the exercise intensity corresponded to a very light intensity[37], as reflected by the modest values for heart rate. It is known that to bring about changes in blood pressure through rhythmic exercise, the intensity needs to be at least moderate to intense[38]. On other hand, as expected, SBP reached greater values in both walking conditions than during rest conditions, and DBP did not differ in any conditions (rest, CON or TYP).

On the other hand, we found that RPE measured immediately after TYP was higher than after CON condition, which correspond to a very light-fairly light exercise intensity and very light exercise intensity, respectively. Moreover, our results showed a poor positive correlation between RPE and heart rate during TYP. Indeed, RPE scale has been correlated (r = 0.80–0.90) with several physiological measures of performance effort, including heart rate during activity[39]; however, we believe that the dissociation found in the present study between RPE and heart rate (different RPE and similar mean heart rate) may be explained by difficult of the participants differentiate RPE from discomfort. In addition, RPE measured immediately after TYP and CON conditions

Our study is not without limitation. First, other physiological measures, like oxygen uptake, were not measured due lack of specific equipment. The assessment of other physiological measures could bring further insight into the topic, since there is evidence about a negative relationship between cell phone use and cardiorespiratory fitness[40]. Second, our study sample is based only on a cohort of healthy male adults with mean age of 23.1 years old. Considering that healthy adults present normal or high aerobic physical fitness, it is reasonable to assume that walk while typing in clinical people, such as older adults and people with non-communicable disease, perform this dual-task may represent a high fraction of maximal aerobic fitness. Thus, future studies must be conducted to elucidate this matter. Also, as young individuals usually have better coordinate ability than elderlies, future studies are need with this population. Third, the stride length measure used is not the best method to measure a fundamental biomechanical feature; however, it was not possible to use a more robust method in our laboratory. Finally, stride parameters were measured during a treadmill walking and therefore, it may not represent a real-life walking. Nevertheless, we believe that these limitations do not prevent the study from drawing conclusions.

5. Conclusion

Five minutes of TYP at constant smartphone use changed rating of perceived exertion and biomechanics but not physiological parameters during gait on treadmill in healthy men compared to a walking control condition.

Author Contributions: R.V., C.G. and C.L design the study; R.V. and C.G. performed the review of literature and contributed to acquisition of data; R.V. analyzed the data; R.V. and C.L wrote the paper; C.G., P.G., D.S., M.C., C.A., R.L.V. and M.A. critically revised the paper; All authors contributed to revision of the paper.

Funding: Not Applicable.

Ethics Committee: All experimental procedures were approved by the University Human Research Ethics Committee (April 25, 2017, no. 1.459.010).

Conflict of interests: The authors declare that there is no conflict of interest.

References

1. McIlroy, T. Planet of the phones. Available online: http://www.economist.com/news/leaders/21645180-smartphone-ubiquitous-addictive-and-transformative-planet-phones (accessed on Mar 10, 2020).
2. Willemse, I.; Waller, G.; Genner, S.; Suter, L.; Oppliger, S.; Huber, A.L.; Süss, D. JAMES: Youth, Activities, Media– Survey Switzerland. In Proceedings of the Zürcher Hochschule für angewandte Wissenschaften; Zürich, **2014**, p. 67.
3. IBGE Instituto Brasileiro de Geografia e Estatística Available online: http://www.ibge.gov.br/home/estatistica/populacao/acessoainternet2014/default_xls.shtm (accessed on Mar 10, 2020).
4. Nordin, E.; Moe-Nilssen, R.; Ramnemark, A.; Lundin-Olsson, L. Changes in step-width during dual-task walking predicts falls. *Gait Posture* **2010**, *32*, 92–97, doi:10.1016/j.gaitpost.2010.03.012.
5. Parr, N.D.; Hass, C.J.; Tillman, M.D. Cellular phone texting impairs gait in able-bodied young adults. *J. Appl. Biomech.* **2014**, *30*, 685–688, doi:10.1123/jab.2014-0017.
6. Klauer, S.G.; Guo, F.; Simons-Morton, B.G.; Ouimet, M.C.; Lee, S.E.; Dingus, T.A. Distracted driving and risk of road crashes among novice and experienced drivers. *N. Engl. J. Med.* **2014**, *370*, 54–59, doi:10.1056/NEJMsa1204142.
7. Shelton, J.T.; Elliott, E.M.; Lynn, S.D.; Exner, A.L. The distracting effects of a ringing cell phone: An investigation of the laboratory and the classroom setting. *J. Environ. Psychol.* **2009**, *29*, 513–521, doi:10.1016/j.jenvp.2009.03.001.
8. Yogev-Seligmann, G.; Rotem-Galili, Y.; Mirelman, A.; Dickstein, R.; Giladi, N.; Hausdorff, J.M. How does explicit prioritization alter walking during dual-task performance? Effects of age and sex on gait speed and variability. *Phys. Ther.* **2010**, *90*, 177–186, doi:10.2522/ptj.20090043.
9. Schwebel, D.C.; Stavrinos, D.; Byington, K.W.; Davis, T.; O'Neal, E.E.; de Jong, D. Distraction and pedestrian safety: how talking on the phone, texting, and listening to music impact crossing the street. *Accid. Anal. Prev.* **2012**, *45*, 266–271, doi:10.1016/j.aap.2011.07.011.
10. Tesio, L.; Rota, V. The motion of body center of mass during walking: a review oriented to clinical applications. *Front. Neurol.* **2019**, *10*, doi:10.3389/fneur.2019.00999.
11. Waters, R.L.; Mulroy, S. The energy expenditure of normal and pathologic gait. *Gait Posture* **1999**, *9*, 207–231, doi:10.1016/S0966-6362(99)00009-0.
12. Waters, R.L.; Lunsford, B.R.; Perry, J.; Byrd, R. Energy-speed relationship of walking: standard tables. *J. Orthop. Res.* **1988**, *6*, 215–222, doi:10.1002/jor.1100060208.
13. Kerrigan, D.C.; Viramontes, B.E.; Corcoran, P.J.; LaRaia, P.J. Measured versus predicted vertical displacement of the sacrum during gait as a tool to measure biomechanical gait performance. *Am. J. Phys. Med. Rehabil.* **1995**, *74*, 3–8, doi:10.1097/00002060-199501000-00002.
14. Santos-Concejero, J.; Granados, C.; Irazusta, J.; Bidaurrazaga-Letona, I.; Zabala-Lili, J.; Tam, N.; Gil, S.M. Influence of the biomechanical variables of the gait cycle in running economy. *Rev. Int. Cienc. Deporte* **2014**, *10*, 95–108, doi:10.5232/ricyde2014.03601.
15. Borg, G.A. Psychophysical bases of perceived exertion. *Med. Sci. Sports Exerc.* **1982**, *14*, 377–381.
16. Noakes, T.D. Linear relationship between the perception of effort and the duration of constant load exercise that remains. *J. Appl. Physiol.* **2004**, *96*, 1571–1573, doi:10.1152/japplphysiol.01124.2003.
17. Canadian Society for Exercise Physiology Physical Activity Readiness Questionnaire - PAR-Q. **2002**.

18. Powers, S.K.; Howley, E.T. *Exercise physiology: Theory and application to fitness and performance*; 10th ed.; McGraw-Hill Education: New York, **2017**; ISBN:978-1-259-87045-3.
19. Plowman, S.A.; Smith, D.L. *Exercise physiology for health, fitness, and performance*; 2nd ed.; Wolters Kluwer Health/Lippincott Williams & Wilkins: Philadelphia, **2008**; ISBN 9780781784061.
20. Mian, O.S.; Thom, J.M.; Ardigo, L.P.; Narici, M. V.; Minetti, A.E. Metabolic cost, mechanical work, and efficiency during walking in young and older men. *Acta Physiol.* **2006**, *186*, 127–139, doi:10.1111/j.1748-1716.2006.01522.x
21. Sloot, L.H.; van der Krogt, M.M.; Harlaar, J. Self-paced versus fixed speed treadmill walking. *Gait Posture* **2014**, *39*, 478–484, doi:10.1016/j.gaitpost.2013.08.022.
22. Sloot, L.H.; van der Krogt, M.M.; Harlaar, J. Effects of adding a virtual reality environment to different modes of treadmill walking. *Gait Posture* **2014**, *39*, 939–945, doi:10.1016/j.gaitpost.2013.12.005.
23. Scherr, J.; Wolfarth, B.; Christle, J.W.; Pressler, A.; Wagenpfeil, S.; Halle, M. Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. *Eur. J. Appl. Physiol.* **2013**, *113*, 147–155, doi:10.1007/s00421-012-2421-x.
24. Munro, B.H. *Statistical methods for health care research*; JB Lippincott: Philadelphia, **1986**; ISBN 078172175X.
25. Cohen, J. *Statistical power analysis for the behavioral sciences statistical power analysis for the behavioral sciences*; 2nd ed.; Lawrence Erlbaum Associates: Hillsdale-New Jersey, **1988**. ISBN: 0-8058-0283-5.
26. Lamberg, E.M.; Muratori, L.M. Cell phones change the way we walk. *Gait Posture* **2012**, *35*, 688–690, doi:10.1016/j.gaitpost.2011.12.005.
27. Demura, S.; Uchiyama, M. Influence of cell phone email use on characteristics of gait. *Eur. J. Sport Sci.* **2009**, *9*, 303–309, doi:10.1080/17461390902853069.
28. Hollman, J.H.; McDade, E.M.; Petersen, R.C. Normative spatiotemporal gait parameters in older adults. *Gait Posture* **2011**, *34*, 111–118, doi:10.1016/j.gaitpost.2011.03.024.
29. Hashish, R.; Toney-Bolger, M.E.; Sharpe, S.S.; Lester, B.D.; Mulliken, A. Texting during stair negotiation and implications for fall risk. *Gait Posture* **2017**, *58*, 409–414, doi:10.1016/j.gaitpost.2017.09.004.
30. Niederer, D.; Bumann, A.; Mühlhauser, Y.; Schmitt, M.; Wess, K.; Engeroff, T.; Wilke, J.; Vogt, L.; Banzer, W. Specific smartphone usage and cognitive performance affect gait characteristics during free-living and treadmill walking. *Gait Posture* **2018**, *62*, 415–421, doi:10.1016/j.gaitpost.2018.04.007.
31. Tian, Y.; Huang, Y.; He, J.; Wei, K. What affects gait performance during walking while texting? A comparison of motor, visual and cognitive factors. *Ergonomics* **2018**, *61*, 1507-1518, doi:10.1080/00140139.2018.1493153.
32. Magnani, R.M.; Lehnen, G.C.; Rodrigues, F.B.; de Sá e Souza, G.S.; de Oliveira Andrade, A.; Vieira, M.F. Local dynamic stability and gait variability during attentional tasks in young adults. *Gait Posture* **2017**, *55*, 105–108, doi:10.1016/J.GAITPOST.2017.04.019.
33. Pizzamiglio, S.; Naeem, U.; Abdalla, H.; Turner, D.L. Neural Correlates of Single- and Dual-Task Walking in the Real World. *Front. Hum. Neurosci.* **2017**, *11*, 1–12, doi:10.3389/fnhum.2017.00460.
34. Agostini, V.; Lo Fermo, F.; Massazza, G.; Knaflitz, M. Does texting while walking really affect gait in young adults? *J. Neuroeng. Rehabil.* **2015**, *12*, 86, 1-10, doi:10.1186/s12984-015-0079-4.
35. Kodesh, E.; Kizony, R. Measuring cardiopulmonary parameters during dual-task while walking. *J. Basic Clin. Physiol. Pharmacol.* **2014**, *25*, 155–60, doi:10.1515/jbcpp-2013-0123.
36. Schabrun, S.M.; van den Hoorn, W.; Moorcroft, A.; Greenland, C.; Hodges, P.W. Texting and Walking: Strategies for Postural Control and Implications for Safety. *PLoS One* **2014**, *9*, e84312, doi:10.1371/journal.pone.0084312.
37. Garber, C.E.; Blissmer, B.; Deschenes, M.R.; Franklin, B.A.; Lamonte, M.J.; Lee, I.-M.; Nieman, D.C.; Swain, D.P. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in

apparently healthy adults. *Med. Sci. Sports Exerc.* **2011**, *43*, 1334–1359, doi:10.1249/MSS.0b013e318213fefb.

38. Pescatello, L.S.; Franklin, B.A.; Fagard, R.; Farquhar, W.B.; Kelley, G.A.; Ray, C.A.; American College of Sports Medicine American College of Sports Medicine position stand. Exercise and hypertension. *Med. Sci. Sports Exerc.* **2004**, *36*, 533–553, doi:10.1249/01.mss.0000115224.88514.3a.
39. Borg, G.A. Perceived exertion: a note on "'history'" and methods. *Med. Sci. Sports* **1973**, *5*, 90–93.
40. Lepp, A.; Barkley, J.E.; Sanders, G.J.; Rebold, M.; Gates, P. The relationship between cell phone use, physical and sedentary activity, and cardiorespiratory fitness in a sample of U.S. college students. *Int. J. Behav. Nutr. Phys. Act.* **2013**, *10*, 79, doi:10.1186/1479-5868-10-79.