Patient-reported Outcome versus Performance-based Variations of Talk Test: A Baseline Comparison of Utterance Characteristics

Siti R. Mahmod, Aqilah L. Narayanan, and Eko Supriyanto*

Abstract—Most versions of TT use individual-reported speaking comfort while exercising to estimate exercise intensity. Currently, only one variation, called the Counting TT, has been used to estimate exercise intensity based on speech utterance performance during exercises and at resting condition. Consistency and repeatability of temporal utterances during the resting TT is of considerable relevance for research and clinical settings to serve as a crucial baseline so that the changes in cardiorespiratory exertion during exercises can be determined accurately. Sixteen participants read aloud the following standard passages: (a) the 'Pledge of Allegiance of the United States (PA)', (b) the 'nineteenth article of the Italian Constitution (IC)' and, (c) the Counting TT (CTT) at their usual talking pace. PA and IC were patient-reported outcome variation of TT while CTT was a performance-based TT. All TT transcripts were in English and uttered for two repetitions at two different sessions. PA and IC were uttered with significant differences of number of pauses and utterance duration either across sessions or test repetitions ($p < 0.05$). Only CTT possessed consistent temporal utterances across repetitions and sessions ($p > 0.05$) and had the highest intra session repeatability for all its utterance variables (ICC ≥ 0.83) except for the number of pauses. Inter-session repeatability of CTT utterance rate and articulation rate were slightly lower at ICC ≤ 0.78. Our findings suggest that pause occurrences may be important sources of inconsistency and unreliability of temporal structure of utterance in the existing variations of TT.

.

***Keywords*—**Patient-reported outcome measure, Performance-based measure, Repeatability, Talk Test

I. Introduction

Talk Test (TT) is a valid and practical assessment tool for exercise intensity estimation [1], [2] in both clinical [3]–[6] and non-clinical populations [7]–[11]. The concept of speaking while exercising at one's own volition creates a competition between breathing patterns required for linguistic phrasing and breathing patterns required for exercising [12]. Thus, upon reading completion of a standard passage at various stages of incremental exercise, the individual's reports of speaking comfort are assessed and categorised as either positive, equivocal or negative TT. Such patient/person-reported outcome measure (PROM) in the TT may allow physiotherapists or other healthcare professionals to track impact of exercise intervention and aid optimal management strategy. Patient-reported outcomes measures (PROMs) are defined as "..any report of the status of a patient's health condition that comes directly from the patient, without interpretation of the patient's response by a clinician or anyone else" [13].

Currently, only one version, called the Counting TT, has been used to estimate exercise intensity based on performance measure of utterances during exercises and at resting condition [11], [14]. Performance-based measures are defined as assessor observed measures of tasks classified as "activities" using the International Classification of Functioning, Disability and Health model [15]. Performance-based measures assess what an individual can do rather than what the individual perceives they can do. Despite the wide variety of standard passages were used in the patient-reported TT such as the Pledge of Allegiance (PA) [3], [8], [10], [16]–[21], the nineteenth article of the Italian Constitution (IC) [6], the Danish text passage [22], the Spanish poem 'Song of the Pirate' [23], and in the performance-based TT such as the Counting Talk Test (CTT) [11], [24], consistency and repeatability of utterance variables in either variations of TT have not been examined.

The difficulty of speech utterances was found to be strongly associated with pulmonary ventilation and oxygen consumption [25]. Previous study has showed that a pre-determined utterance rate of 60-70 words/minute during exercising resulted in a consistent reduction of minute ventilation as the exercise intensity increases [26]. Hence, if such utterance rate could be known from resting and exercising TT, the changes of cardiorespiratory exertion corresponding to the TT measure can be more meaningfully interpreted. Therefore, the changes in temporal utterance variables should not be overlooked during the TT, either at resting or exercise condition.

To the best of our knowledge, no study has yet been conducted to investigate the consistency and repeatability of

This work was supported in part by the Universiti Teknologi Malaysia Research Grant.

Siti R. Mahmod is with the Health Science Programme, Faculty of Bioscience and Medical Engineering Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia

A. L. Narayanan, was with Department of Physiotherapy, Hospital Sultanah Aminah 80000 Johor Bahru, Malaysia. She is now with the Department of Clinical Science, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia

*Eko Supriyanto is with Advanced Diagnostics and Progressive Human Care Research Group, IJN-UTM Cardiovascular Engineering Centre, Faculty of Biosciences and Medical Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Malaysia (Corresponding author e-mail: eko@utm.my)

utterance variables in any TT versions. As such, this study was designed to assess consistency and repeatability (i.e, test-retest) of temporal structure of utterances in two variations of TT (i.e., patient-reported and performance-based outcome) at rest across test repetitions and sessions.

II. METHODOLOGY

A. Participants

Sixteen young adults (8 men, 8 women; 25 ± 3 years old) who were recruited from the Universiti Teknologi Malaysia (UTM) volunteered to undergo this study in the cardiorespiratory physiotherapy laboratory of UTM. All participants had no known history of respiratory, speech or hearing problems. The test procedure was explained to the participants and written informed consent was obtained from them prior to their participation in the present study. The study received approval from the medical research ethics committee, Ministry of Health Malaysia regarding research with humans (NMRR-15-1614-27729).

B. Experimental Procedure

Two sessions of talk testing were conducted on 2 different days with an average of 8 days apart. The participants were asked to perform the TTs for two sets of repetitions (i.e., test and retest) per session in the following order: (1) the Pledge of Allegiance (PA), (2) the nineteenth article from the Italian Constitution (IC), and (3) the Counting Talk Test (CTT). They were required to recite PA and IC aloud until the last word. In the CTT, the participants were asked to count out aloud as many numbers as possible at their usual talking pace in one deep breath. They were asked to count the following sequence: "one-one thousand, two-one thousand, three-one thousand," and so on, before taking a second breath [11]. Moreover, the participants were given pre-test trials to familiarise them with the text passages and the counting protocol. At each TT, the participants were instructed to ensure that they were loud enough to be clearly audible to an observer sitting about 2 meters away. All the tests were conducted inside a closed room with no disturbance or distraction.

The standard paragraphs and counts to be recited out loud were displayed on an 18.5-inch LCD computer monitor situated at eye level with the distance of 0.8 metres in front of the participants, whilst they were seated comfortably on a standard, height-adjustable office chair with armrests and both feet on the floor. Prior to the TT, a physiological monitoring system (BioHarness®, Zephyr Technology, Auckland, New Zealand) was affixed to each participant's chest and their breathing and heart rates were recorded after 5 minutes of rest in a relaxed sitting. This system was also used to monitor breathing rate during the TT. Special attention was paid during the counting phase since accurate tracking of counts in a single deep breath is of paramount importance, as according to [26], utterance-related hypoventilation is indicated by a significant reduction in breathing rate.

C. Data Acquisition

The participants' speech utterances were recorded using a built-in monophonic computer microphone and saved into the Praat voice analysis computer software program [27]. The utterance signals were sampled at 44.1 kHz and saved in the waveform audio files format (wav). A calibrated sound level meter (CEL-240, Casella CEL Inc., Buffalo, New York) was kept at a constant mouth-to-microphone distance of 30 cm with a 0º mouth-to-microphone orientation. It was connected via USB cable to the CEL dB24 software which was used as a data logger for real-time measurement of changes in sound pressure level (in decibels). The sound level meter was set for c-weighting.

D. Data Processing

The signals of speech utterance were band-pass filtered between 20 Hz and 20 kHz using the spectral subtraction method as provided in the Praat software package [27]. The filtered signals and their corresponding TextGrids were then processed to determine the spurt length, at the beginning and the end of each actual utterance, and later saved as a *.wav file. A total of 96 sound files were analysed by a validated Praat script [28]. The script was used to compute the temporal utterance variables including number of pauses, utterance duration, phonation time (excluding the pauses), utterance rate and articulation rate. The utterance rate and articulation rate were defined as the number of syllables divided by the total time and the number of syllables divided by phonation time, respectively [28] while the phonation time excluded the duration of pauses. The Praat script was executed at a silence threshold of –25dB with the minimum dip between peaks at 2dB and the minimum pause durations of 0.3 s.

E. Data Analysis

All statistical analyses were carried out using the SPSS software package (Version 16.0; Chicago, SPSS Inc.). The influence of time, in terms of sessions and repetitions (tests and retests) on the utterance variables, was tested using analysis of variance (ANOVA) for repeated data, with the TTs defined as one independent variable. Meanwhile, the test sessions (session 1 and session 2) and repetition (test and retest) were taken as the repeated factors. The statistical significance for each variable was set at p-value < 0.05.

The intra-session repeatability of all the variables was assessed using a reliability coefficient that was computed using the following formula:

$$R = \frac{\sigma_t^2}{\sigma_t^2 + \sigma_e^2}$$

Theoretically, the term σ_t^2 is considered as a variance of true score while σ_e^2 corresponds to variance of error. Both values contribute towards the total variance in a group of measurements. However, as the true score for each subject is unknown, a two-way random model of the intra class correlation coefficient (ICC) was used to estimate relative reliability; ICC (2,1) for intrasession repeatability and ICC (2,2) for intersession repeatability [29]. The above-mentioned variable is a ratio between intra class variance and the total variance (as obtained from ANOVA) and can range from as low as 0 to as high as 1.0. For each ICC, a 95% confidence interval (CI) was reported to illustrate the precision of the estimates. In addition, the standard error of measurement (SEM), which is the estimate of absolute reliability, was determined as the square root of the mean square error term which was obtained from ANOVA [30].

III. RESULTS

Generally, all the TTs were uttered with significantly different mean number of syllables (PA= 49 ± 6, IC=65 ± 7 and CTT=112 ± 36 syllables). From Table 1a to c, participants demonstrated consistent vocal sound intensity across test repetitions and sessions in all the TTs except for the PA. Only the CTT was performed with all utterance variables remain consistent across session and test repetitions ($p > 0.05$), whereas in PA and IC, their utterance duration and number of pauses were in common, changed over time ($p < 0.05$).

Table 1. Temporal utterance variables and vocal sound intensity in 3 Talk Tests.

(a) PA

	Session 1		Session 2		ANOVA	
Utterance variables	Test	Retest	Test	Retest	*p* session	*p* repetition
Npause[a]	3 (3)	3 (2)	2 (2)	2 (2)	0.006*	0.558
Utterance dur[b] (s)	12.24 (1.28)	11.56 (0.92)	11.67 (1.20)	11.44 (1.38)	0.147	0.007*
Phontime[c] (s)	10.64 (0.77)	10.34 (0.92)	10.69 (1.08)	10.45 (1.22)	0.661	0.048*
Utterance rate (syll[d]/s)	4.03 (0.60)	4.33 (0.53)	4.24 (0.47)	4.16 (0.65)	0.808	0.237
Articrate [e] (syll/s)	4.59 (0.43)	4.84 (0.58)	4.63 (0.53)	4.54 (0.66)	0.207	0.472
Vocal intensity (dB)	67.63 (2.87)	68.72 (3.63)	67.51 (3.06)	68.79 (3.68)	0.936	0.007*

(b) IC

	Session 1		Session 2		ANOVA	
Utterance variables	Test	Retest	Test	Retest	*p* session	*p* repetition
Npause[a]	4 (2)	3 (2)	3 (2)	2 (2)	0.001*	0.028*
Utterance dur[b] (s)	16.51 (1.59)	15.62 (1.19)	15.53 (1.51)	15.28 (1.55)	0.017*	<0.01*
Phontime[c] (s)	14.46 (1.66)	13.93 (1.22)	14.17 (1.66)	14.18 (1.46)	0.942	0.231
Utterance rate (syll[d]/s)	4.06 (0.47)	4.05 (0.35)	4.26 (0.38)	4.30 (0.42)	0.006*	0.819
Articrate [e] (syll/s)	4.65 (0.56)	4.54 (0.47)	4.67 (0.41)	4.64 (0.45)	0.416	0.196
Vocal intensity (dB)	68.74 (2.83)	69.06 (3.76)	68.74 (2.83)	69.06 (3.76)	0.748	0.326

(c) CTT

	Session 1		Session 2		ANOVA	
Utterance variables	Test	Retest	Test	Retest	*p* session	*p* repetition
Npause[a]	3 (3)	2 (2)	2 (3)	2 (2)	0.424	0.282
Utterance dur[b] (s)	22.91 (6.13)	23.27 (7.66)	22.60 (6.49)	23.09 (5.67)	0.743	0.283
Phontime[c] (s)	21.78 (6.36)	22.45 (7.03)	21.64 (6.29)	22.22 (6.00)	0.804	0.129
Utterance rate (syll[d]/s)	4.84 (0.75)	4.92 (0.76)	4.89 (0.61)	4.89 (0.59)	0.921	0.416
Articrate [e] (syll/s)	5.12 (0.82)	5.07 (0.74)	5.10 (0.60)	5.09 (0.48)	0.977	0.590
Vocal intensity (dB)	69.20 (3.14)	69.37 (3.37)	69.2 (3.14)	69.37 (3.37)	0.727	0.820

Analysis of utterance variables in the TTs over time was extended to test-retest reliability (repeatability) which was represented by intra-class correlation coefficient (ICC) and reliability (ICC>0.75) [31] but a decrease in ICC values for their rate of utterance and articulation. Meanwhile, ICC and SEM analysis of the CTT showed either good or excellent intrasession repeatability [31] for all utterance variables in both sessions (ICC range: 0.83-0.97), where the only notable exception was the number of pauses.

Values in Table 1 a to c are presented as mean (standard deviation).
* significant differences ($p < 0.05$)
[a] number of pauses; [b] duration; [c] phonation time; [d] syllables; [e] articulation rate

Table 2. Repeatability of temporal utterance variables and vocal intensity in 3 Talk Test variation.

Utterance variables	Talk Test	Intra-session 1 ICC $_{(2,1)}$	95% CI	Intra-session 2 ICC $_{(2,1)}$	95% CI	Inter-session ICC $_{(2,2)}$	95% CI	SEM
Npause	PA	0.46	0.02-0.77	0.82	0.56-0.94	0.72	0.20-0.90	1.20
	IC	0.61	0.20-0.84	0.82	0.53-0.94	0.72	0.07-0.91	1.07
	CTT	0.31	0.21-0.69	0.59	0.16-0.83	0.54	0.08-0.81	2.13
Utterance dur (s)	PA	0.67	0.08-0.89	0.85	0.63-0.94	0.68	0.31-0.87	0.89
	IC	0.74	0.03-0.93	0.91	0.76-0.97	0.70	0.26-0.89	0.98
	CTT	0.95	0.86-0.98	0.93	0.83-0.98	0.90	0.75-0.97	2.91
Phontime (s)	PA	0.47	0.01-0.77	0.90	0.72-0.96	0.76	0.43-0.91	0.68
	IC	0.54	0.11-0.81	0.90	0.73-0.96	0.67	0.27-0.87	1.17
	CTT	0.97	0.91-0.99	0.93	0.81-0.97	0.90	0.73-0.96	2.94
Utterance rate (nsyll/dur)	PA	0.61	0.15-0.85	0.49	0.01-0.79	0.79	0.50-0.92	0.33
	IC	0.77	0.44-0.91	0.68	0.29-0.88	0.63	0.10-0.86	0.28
	CTT	0.92	0.79-0.97	0.85	0.62-0.95	0.78	0.48-0.92	0.45
Articrate (nsyll/phontime)	PA	0.57	0.14-0.83	0.52	0.05-0.80	0.68	0.31-0.87	0.39
	IC	0.77	0.47-0.91	0.63	0.2-0.85	0.795	0.51-0.92	0.28
	CTT	0.91	0.77-0.97	0.83	0.57-0.94	0.65	0.23-0.86	0.56
Vocal sound intensity (dB)	PA	0.82	0.49-0.94	0.78	0.40-0.92	0.91	0.76-0.97	1.39
	IC	0.90	0.75-0.97	0.87	0.68-0.95	0.88	0.69-0.96	1.62
	CTT	0.93	0.80-0.97	0.93	0.81-0.98	0.82	0.56-0.93	2.04

IV. DISCUSSION

In Table 1a, the PA was not uttered within a consistent vocal intensity over time by participants as other TTs even at resting condition. Effects of varied vocal intensity on ventilation [32] and a strong association between pulmonary ventilation and speech utterance production [33] would explain the inconsistent of utterance duration and phonation time shown in PA. There is a possibility that varied vocal intensity during TT (i.e. PA) might occur while exercising too which affect energy expenditure and ventilation [32]. Energy expenditure is a measure of exercise intensity [34]. Thus, a patient-reported outcome of TT for estimating exercise intensity may be confounded by vocal intensity of TT utterance.

Meanwhile, in Table 1b, there was a significant difference in the IC utterance rate across sessions even in resting condition that can be potentially due to inconsistent number of pauses and utterance duration over time. A pre-determined utterance rate during exercising resulted in a consistent reduction of minute ventilation as the exercise intensity increases [35]. If such utterance rate could be fixed from resting to exercising TT, the changes of cardiorespiratory exertion corresponding to the patient-reported TT measure can be more meaningfully interpreted. Hence, it can be postulated hat the IC might be complex for a present study's participants to utter consistently over time because of some difficult words pronunciation for whom participants were not native speakers for English language. Compared to first language speakers, second language speakers have been demonstrated to have higher pause rate at the clause boundary [36].

On the other hand, a previous study had reported that resting or baseline CTT produced consistent count amongst multiple sessions [11]. The consistent count in CTT might be a result of its consistent temporal utterance structure as demonstrated in a present study (Table 1c).

From Table 2, low and moderate ICC values for the number of pauses in CTT were recorded in intrasession 1 and 2, respectively. The intersession repeatability of number of pauses in CTT also moderate. The occurrence of pauses, to a considerable extents depends on the specific speaker, where a greater number of pauses is associated to weak respiration, low muscular tone and slow articulation rate [37]. However, these aspects are not relatable for our healthy speakers who have no known respiratory, speech and language and cognitive constraints. In the present study, the pauses in CTT utterances were noticeably occurred between multi-syllabic phrases of one count to the subsequent count. In addition, the differentiation of the phrases was achieved by variations of the melody and by the variations of utterance duration. In this regard, the silent pauses appeared in the utterance signal of CTT may be produced as the result of inspiration, swallowing, laryngo-phonatory reflex, or a silent expiration [37]. Although CTT was required to be uttered within an individual inspiratory capacity that may minimise the physiological, inevitable pauses which regularly occur during inspiratory phase of respiratory cycle, utterance production is still considered to be a rhythmic activity. Hence, the variations in inter-session articulation rate can be induced by the durational structure of speech utterance, especially in the case of words with more than two syllables [38]. Besides that, the complexity (length or type) of the text to be spoken [39] and rib cage compliance [40] were some factors related to utterance variability. Since rib cage compliance varies individually by age and posture[41], therefore, repeatability of temporal utterance variables in TT may be improved if the complexity of text for utterance is minimised. Otherwise, the rate of utterance can be varied within the same utterances even in normal, highly fluent speakers [42].

Assessments of consistency and repeatability of temporal utterance structure in the baseline TT (before exercise) is of considerable important for research and clinical settings. Baseline TT may serve as a crucial reference for individuals in determining valid changes in cardiorespiratory exertion during incremental exercise testing and in progressing their exercise training programs towards optimal targets especially in clinical populations. patients with different baseline exercise capacity had relatively different improvement in exercise capacity and in other related clinical outcomes (i.e. after cardiac rehabilitation) [43]. Situational contexts such as the increase in cardiorespiratory exertion may cause utterance difficulty which results in more pauses, hesitations and stuttering [37]. In this light, when the temporal utterance structure of the TT is not stable over time, estimation of exercise intensity whether using patient-reported outcome or performance based TT may not be well interpreted.

V. CONCLUSION

The performance-based variation of TT which is represented by CTT appeared to be moderate to highly repeatable for its temporal utterance structure within and between sessions, except for the number of pauses. The pauses were produced spontaneously by the participants during the CTT since utterance production is a rhythmic activity. As such, it may be intriguing to exploit the occurrence of pauses and generate patterned pauses in the TT though this perspective needs to be further investigated in future studies at a baseline, as well as in various stages of incremental exercise.

ACKNOWLEDGMENT

S.R Mahmod would like to thank all the participants in this study and cordially grateful to the Department of Clinical Science, Universiti Teknologi Malaysia (UTM) for providing all facilities to conduct the experiment.

REFERENCES

[1] J. L. Reed and A. L. Pipe, "The talk test: A useful tool for prescribing and monitoring exercise intensity," *Curr. Opin. Cardiol.*, vol. 29, no. 5, pp. 475–480, 2014.

[2] A. L. Webster and S. Aznar-Laín, "Intensity of physical activity and the 'Talk Test': A brief review and practical application," *ACSM's Heal. Fit. J.*, vol. 12, no. 3, pp. 13–17, 2008.

[3] C. A. Brawner *et al.*, "Guiding exercise using the talk test among patients with coronary artery disease," *J. Cardiopulm. Rehabil. Prev.*, vol. 26, no. 2, pp. 72–75, 2006.

[4] J. Kressler, R. Cowan, K. Ginnity, and M. Nash, "Subjective measures of exercise intensity to gauge substrate partitioning in persons with paraplegia," *Top. Spinal Cord Inj. Rehabil.*, vol. 18, no. 3, pp. 205–211, 2012.

[5] R. Cowan, K. Ginnity, J. Kressler, and M. Nash, "Assessment of the talk test and rating of perceived exertion for exercise intensity prescription in persons with paraplegia," *Top. Spinal Cord Inj. Rehabil.*, vol. 18, no. 3, pp. 212–219, 2012.

[6] R. Zanettini *et al.*, "Validity of the Talk Test for exercise prescription after myocardial revascularization," *Eur. J. Prev. Cardiol.*, vol. 20, no. 2, pp. 376–382, 2013.

[7] J. F. Norman, J. Kracl, D. Parker, and A. Richter, "Comparison of the Counting Talk Test and heart rate reserve methods for estimating exercise intensity in healthy young adults," *J. Exerc. Physiol. Online*, vol. 5, no. 1, 2002.

[8] R. Persinger, C. Foster, M. Gibson, D. C. W. Fater, and J. P. Porcari, "Consistency of the Talk Test for exercise prescription," *Med. Sci. Sports Exerc.*, vol. 36, no. 9, pp. 1632–1636, 2004.

[9] C. Foster *et al.*, "Translation of submaximal exercise test responses to exercise prescription using the talk test.," *J. Strength Cond. Res.*, vol. 23, no. 9, pp. 2425–2429, 2009.

[10] T. J. Quinn and B. A. Coons, "The talk test and its relationship with the ventilatory and lactate thresholds," *J. Sports Sci.*, vol. 29, no. 11, pp. 1175–1182, 2011.

[11] B. D. Loose *et al.*, "Consistency of the counting talk test for exercise prescription," *J. Strength Cond. Res.*, vol. 26, no. 6, pp. 1701–1707, 2012.

[12] S. E. Baker, J. Hipp, and H. Alessio, "Ventilation and speech characteristics during submaximal aerobic exercise.," *J. Speech. Lang. Hear. Res.*, vol. 51, no. 5, pp. 1203–14, 2008.

[13] FDA and HHS, "Guidance for Industry Use in Medical Product Development to Support Labeling Claims Guidance for Industry," *Clin. Fed. Regist.*, no. December, pp. 1–39, 2009.

[14] J. F. Norman, E. Hopkins, and E. Crapo, "Validity of the counting talk test in comparison with standard methods of estimating exercise intensity in young healthy adults," *J. Cardiopulm. Rehabil. Prev.*, vol. 28, no. 3, pp. 199–202, 2008.

[15] World Health Organization. International Classification of Functioning, Disability, and Health. Geneva, Switzerland: ICF; 2001.

[16] C. Foster *et al.*, "The Talk Test as a Marker of Exercise Training Intensity," *J. Cardiopulm. Rehabil. Prev.*, vol. 28, no. 1, p. 24–30 10.1097/01.HCR.0000311504.41775.78, 2008.

[17] S. A. Voelker, C. Foster, J. P. Porcari, K. M. Skemp, G. Brice, and R. Backes, "Relationship between the talk test and ventilatory threshold in cardiac patients," University of Wisconsin--La Crosse, 2001.

[18] E. A. Jeans, C. Foster, J. P. Porcari, M. Gibson, and S. Doberstein, "Translation of exercise testing to exercise prescription using the Talk Test," *J. Strength Cond. Res.*, vol. 25, no. 3, pp. 590–596, 2011.

[19] J. Ballweg, C. Foster, J. Porcari, S. Haible, N. Aminaka, and R. P. Mikat, "Reliability of the talk test as a surrogate of ventilatory and respiratory compensation thresholds," *J. Sport. Sci. Med.*, vol. 12, no. 3, pp. 610–611, 2013.

[20] M. L. Woltmann *et al.*, "Evidence that the Talk Test can be used to regulate exercise intensity," *J. Strength Cond. Res.*, vol. 29, no. 5, pp. 1248–1254, 2015.

[21] B. D. Gillespie, J. J. McCormick, C. M. Mermier, and A. L. Gibson, "Talk Test as a Practical Method to Estimate Exercise Intensity in Highly Trained Competitive Male Cyclists," *J. Strength Cond. Res.*, vol. 29, no. 4, pp. 894–898, 2015.

[22] S. G. Nielsen, L. Buus, T. Hage, H. Olsen, M. Walsøe, and A. Vinther, "The graded cycling test combined with the talk test is reliable for patients with ischemic heart disease," *J. Cardiopulm. Rehabil. Prev.*, vol. 34, no. 4, pp. 276–280, 2014.

[23] J. A. Rodríguez-Marroyo, J. G. Villa, J. García-López, and C. Foster, "Relationship between the talk test and ventilatory thresholds in well-trained cyclists," *J. Strength Cond. Res.*, vol. 27, no. 7, pp. 1942–1949, 2013.

[24] J. F. Norman, E. Hopkins, and E. Crapo, "Validity of the Counting Talk Test in Comparison With Standard Methods of Estimating Exercise Intensity in Young Healthy Adults," *J. Cardiopulm. Rehabil. Prev.*, vol. 28, no. 3, pp. 199–202, 2008.

[25] A. Rotstein, Y. Meckel, and O. Inbar, "Perceived speech difficulty

during exercise and its relation to exercise intensity and physiological responses," *Eur. J. Appl. Physiol.*, vol. 92, no. 4–5, pp. 431–436, 2004.
[26] Y. Meckel, A. Rotstein, and O. Inbar, "The effects of speech production on physiologic responses during submaximal exercise," *Med. Sci. Sports Exerc.*, vol. 34, no. 8, pp. 1337–1343, 2002.
[27] D. Weenink, "Praat: Doing phonetics by computer. Version 5.3.04.," 2010. .
[28] N. de Jong and T. Wempe, "Praat script to detect syllable nuclei and measure speech rate automatically," *Behav. Res. Methods*, vol. 41, no. 2, pp. 385–390, 2009.
[29] P. E. Shrout and J. L. Fleiss, "Intraclass correlations: Uses in assessing rater reliability.," *Psychol. Bull.*, vol. 86, no. 2, pp. 420–428, 1979.
[30] J. P. Weir, "Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM," *J Strength Cond Res*, vol. 19, no. 1, pp. 231–240, 2005.
[31] T. K. Koo and M. Y. Li, "A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research," *J. Chiropr. Med.*, vol. 15, no. 2, pp. 155–163, 2016.
[32] B. A. Russell, F. J. Cerny, and E. T. Stathopoulos, "Effects of Varied Vocal Intensity on Ventilation and Energy Expenditure in Women and Men," *J Speech Lang Hear Res*, vol. 41, no. 2, pp. 239–248, 1998.
[33] A. Rotstein, Y. Meckel, and O. Inbar, "Perceived speech difficulty during exercise and its relation to exercise intensity and physiological responses," *Eur. J. Appl. Physiol.*, vol. 92, no. 4–5, pp. 431–436, 2004.
[34] R. A. Linda S.Pescatello Deborah Riebe, Paul D.Thompson, Ed., *ACSM's Guidelines for Exercise Testing and Prescription 9th Ed. 2014*. Wolters Kluwer Lippincott Williams & Wilkins, 2014.
[35] Y. Meckel, A. Rotstein, and O. Inbar, "The effects of speech production on physiologic responses during submaximal exercise.," *Med. Sci. Sports Exerc.*, vol. 34, no. 8, pp. 1337–43, 2002.
[36] J. Kahng, "Exploring utterance and cognitive fluency of L1 and L2 English speakers: temporal measures and stimulated recall," *Lang. Learn.*, vol. 64, no. 4, pp. 809–854, 2014.
[37] B. Zellner, "Pauses and the temporal structure of speech," in *Fundamentals of speech synthesis and speech recognition*, John Wiley and Sons Ltd., 1994, pp. 41–62.
[38] E. Jacewicz, R. A. Fox, and L. Wei, "Between-speaker and within-speaker variation in speech tempo of American English," *J. Acoust. Soc. Am.*, vol. 128, no. 2, pp. 839–850, 2010.
[39] A. L. Winkworth, P. J. Davis, E. Ellis, and R. D. Adams, "Variability and consistency in speech breathing during reading: lung volumes, speech intensity, and linguistic factors," *J. Speech Hear. Res.*, vol. 37, no. 3, pp. 535–556, 1994.
[40] G. Kalliakosta, C. Mandros, and G. E. Tzelepis, "Chest wall motion during speech production in patients with advanced ankylosing spondylitis," *J Speech Lang Hear Res*, vol. 50, no. 1, pp. 109–118, 2007.
[41] M. Estenne, J. C. Yernault, and A. De Troyer, "Rib cage and diaphragm-abdomen compliance in humans: effects of age and posture," *J. Appl. Physiol.*, vol. 59, no. 6, pp. 1842–1848, 1985.
[42] J. L. Miller, F. Grosjean, and C. Lomanto, "Articulation rate and its variability in spontaneous speech: a reanalysis and some implications," *Phonetica*, vol. 41, no. 4, pp. 215–225, 1984.
[43] C. J. Lavie and R. V Milani, "Cardiac Rehabilitation and Exercise Training in Secondary Coronary Heart Disease Prevention," *Prog. Cardiovasc. Dis.*, vol. 53, no. 6, pp. 397–403, 2011.