



A reliability study on the cumulative averaging method for estimating effective stimulus time in vibration studies

Aysegül Kilic^a, Gülsah Soytürk^a, Ayse Karaoglu^c, Betilay Topkara Arslan^b, Ilhan Karacan^{a,*},
Kemal S. Türker^{b,*}

^a Istanbul Physical Therapy Rehabilitation Training and Research Hospital, Istanbul, Turkey

^b Istanbul Gelisim University, Faculty of Dentistry, Avcilar, Istanbul, Turkey

^c Istanbul Gelisim University, Faculty of Engineering, Avcilar, Istanbul, Turkey

ARTICLE INFO

Keywords:

Cumulative average method
Whole-body vibration
Reflex latency
Intra-observer error
Precision error

ABSTRACT

Finding the reflex circuitry responsible for high-frequency vibration-induced muscle contraction takes work. The main challenge is to determine the effective stimulus time (EST) point at which continuous (sinusoidal) stimulation (i.e., vibration) triggers the reflex response. A novel “cumulated averaging method” has been previously proposed for estimating the EST point. In the current study, we aimed to test the reliability of the cumulated average method. We used five different whole-body vibration (WBV) frequencies in two experiments. The consistency between the EST points estimated from the first and second experiments was analysed with the intraclass correlation (ICC) and technical error of measurement (TEM). The ICC coefficient with 95% CI for the EST point estimation was 0.988 (0.950–0.997). The relative TEM was 1.3%. We concluded that the cumulated average method is highly reliable in estimating the effective stimulus time point for high-frequency continuous sinusoidal signals.

1. Introduction

It is known that whole-body vibration (WBV) has beneficial effects on neuromuscular performance and increases muscle strength (Aydin et al., 2020; Cidem et al., 2014); therefore, there is considerable interest in WBV exercises in sports, rehabilitation, and fitness. Although the physiological mechanisms underlying the beneficial neuromuscular effects of WBV are not fully understood, researchers have suggested that spinal responses and spinal reflexes can explain part of this effect (Cakar et al., 2015; Karacan et al., 2017, 2016; Karacan et al., 2009; Karacan and Türker, 2020; Ritzmann and Mileva, 2020; Yildirim et al., 2020).

Reflex latency measurement is often used in clinical and neurophysiological research to understand the receptors and circuitries responsible for the reflex. Although the effects of WBV are well discussed, the latency of the reflex induced by WBV is often ignored because the period between two consecutive vibration stimuli is shorter than the reflex latency expected in a neuronal circuit, and the vibration is a continuous sinusoidal stimulus. Researchers have used the cumulant density function method of Halliday and co-workers (1995) to solve

such problems (Sowman et al., 2006). This method reveals the relationship between the two synchronously recorded signals due to their lag (Halliday and Rosenberg, 1999). Although the cumulant density function effectively uses the peaks of signals to estimate the lag time, this method does not indicate the exact time of the effective stimulus (effective stimulus time; EST) in the signal.

Providing the EST, i.e., the exact location of the effective mechanical stimulus in time along one period of a vibration cycle, is crucial to indicate the exact reflex latency. It was previously suggested that the EST induced by WBV could be estimated using a novel technique, the cumulated averaging method (Karacan et al., 2014). Although this method was tested successfully (Karacan et al., 2014) against the only other available method for the same purpose (cumulant density function analyses of Halliday et al., 1995), no reliability study was performed previously. A reliability study is needed since we had several assumptions for developing the cumulative averaging method: Firstly, we assumed that the receptors respond to the acceleration of the vibration. Earlier studies support this assumption for muscle spindle primary endings (Poshina et al., 1976). Secondly, we assumed that each

* Corresponding authors at: Istanbul Physical Therapy Rehabilitation Training and Research Hospital, Kocasinan Merkez Mahallesi Karadeniz Caddesi No: 48 Bahçelievler/Istanbul, Turkey (I. Karacan).

E-mail addresses: ilhankaracan@hotmail.com (I. Karacan), ksturker@gelisim.edu.tr (K.S. Türker).

<https://doi.org/10.1016/j.jelekin.2023.102768>

Received 6 February 2022; Received in revised form 6 March 2023; Accepted 15 March 2023

Available online 20 March 2023

1050-6411/© 2023 Elsevier Ltd. All rights reserved.

vibration frequency activates the receptors at the same level of acceleration no matter what the vibration frequency was. Thirdly, we assumed that the exact effective stimulation point could be found by trigger averaging the acceleration data using the peaks of rectified EMG as triggers. Finally, we assumed that the peaks of rectified EMG represent reflexly activated motor units. We have previously published this method and used simulations to test its usefulness in indicating the effective stimulus time point and its superiority over the other methods (Karacan et al., 2014). We wished to test its reliability in the current study since we had several assumptions in developing this technique. In this study, we attempted to test the reliability of this method two times and compare the effective stimulation time point and the entire error curves using intraclass correlation (ICC) and the technical error of measurement (TEM). Repeating the same protocol twice is justified since it is well-known that muscles can develop a given force in many different ways, as force comprises the contraction of several agonists and antagonists. Each time a force is developed, a contributing muscle uses its abundance of choice to recruit different portions of muscles, and no two contractions uses identical portions (van Eijden et al., 1990; Scutter and Türker, 1998). Repeating the same stimulus twice, as was done in the current study, is expected to recruit different portions of different muscles. We hypothesised that the effective stimulation time point and error curves would differ between the two attempts.

2. Materials and methods

The study protocol was registered with [ClinicalTrials.gov](https://clinicaltrials.gov/ct2/show/study/NCT05129982) (NCT05129982).

2.1. Participants

Ten healthy volunteers between the ages of 25 and 30 (six males and four females) agreed to participate in this study. A participant with dizziness during the WBV application was excluded from the study. The mean age of the participants who completed the study was 27.2 ± 1.8 years, and the mean height was 174.5 ± 10.7 cm. All participants provided informed consent prior to participation. All experimental procedures were designed with the Helsinki declaration in mind and approved by Kanuni Sultan Suleyman Training and the Research Hospital Ethics Committee (the number/I.D. of the approval: 289 / 2021).

2.2. Testing and analysis procedures

Surface electromyography (sEMG) electrodes were placed on the right soleus muscle belly. Two sets of experimental WBV were applied. The vibration stimulus was recorded using an accelerometer fixed on the WBV platform. Using the cumulated average method, the reflex response induced by the WBV and the effective stimulus time (EST) of the vibration stimulus that initiated this response were determined (Karacan et al., 2014). The reliability of this method was analysed using the intraclass correlation (ICC) and the technical error of measurement (TEM).

2.2.1. Data acquisition

Participants were barefooted, and no sponge or foam was placed between the vibration platform and their feet. The participants stood upright on the vibration platform with their hips and knees in a neutral position. First, 30 Hz, low amplitude (2 mm) vibration with 30 s was applied to each participant for familiarisation. After three minutes of rest, two sets of experimental WBV were applied. In each WBV set, the vibration frequencies (30, 35, 40, 45, 50 Hz) were applied randomly. WBV was applied at each frequency for 30 s with low amplitude (2 mm). The WBV application was delivered using a PowerPlate Pro5 device (PowerPlate International, Amsterdam, The Netherlands).

The vibration stimulus was recorded using an accelerometer (ADXL326, 3-Axis ± 16 g, Analog Devices, Wilmington, MA, USA)

mounted on the WBV platform. To record the reflex responses induced by the vibration stimulus, disposable self-adhesive bipolar Ag/AgCl electrodes (Covidien Kendall, Dublin, Ireland) were attached to the skin on the right soleus muscle belly. The electrodes (10 mm in diameter, inter-electrode distance of 40 mm) were arranged in the direction of the muscle fibres (Tucker and Türker, 2005). Before the electrodes were attached, the skin hairs were shaved, lightly rubbed, cleaned with alcohol, and moisturised with electrode gel. All data were sampled at 40 kHz. sEMG signals were amplified (Dual Bio Amp ML 135, ADInstruments, Oxford, United Kingdom) with a bandwidth frequency ranging from 0.3 Hz to 1000 Hz. Records were obtained using the PowerLab data acquisition system (ADInstruments, Oxford, United Kingdom) and analysed using the LabChart7 software (ver. 7.3.7, ADInstruments, Oxford, United Kingdom).

2.2.2. Determination of the effective stimulus time

The effective stimulus time (EST) point is the mechanical stimulation threshold (Karacan et al., 2014). The coordinate of the mechanical threshold on the sinusoidal mechanical stimulus curve (the phase angle of the mechanical threshold in the vibration sine) depends on the magnitude of the acceleration provided by the WBV. For each frequency, the phase angle of the EST on the sine curve is different (Cidem et al., 2017; Karacan et al., 2014; Rittweger and Tiaar, 2020). The cumulated average method takes advantage of the different phase angle for each frequency. It can determine the exact point of the EST using vibration acceleration data applied to at least three different frequencies (Karacan et al., 2014).

To determine the EST using the cumulated average method, EMG data were bandpass filtered at 80–500 Hz to reduce vibration-induced movement artifacts, and then full-wave rectified (Sebik et al., 2013). The peaks of spikes in the rectified EMG were marked as the trigger points to be used in a spike-triggered averaging scheme. Spike-triggered averaging was performed using these peaks in the EMG data as triggers and vibration records (acceleration data) as sources. The averaging process covered 75 ms of the vibration data preceding the trigger and 15 ms after. This process was performed separately for each of the five vibration frequencies. Then, the average curves plotted for each frequency were superimposed to obtain a cumulated average method. The standard error (S.E.) of the averaged acceleration data of the five vibration frequencies covered by the cumulative averaging curve was calculated for every 3000 bins in the averaging window, from -75 to $+15$ ms of the trigger. The lowest S.E. point was determined in the S.E. curve to indicate the EST point in the cumulative averaging curve of the acceleration. The reflex latency was calculated as the period between the effective stimulus time point and the onset of reflex response. Therefore, similar averaging procedures were applied to EMG recordings to determine the “onset of reflex response” time. The lowest point in the S.E. of the cumulative averaging curve of rectified EMG was marked as the onset of the reflex response (Fig. 1).

2.3. Statistical analysis

The normal distribution of the data was confirmed using the Shapiro–Wilk test. The arithmetic means and standard deviations (S.D.s) were calculated for each variable. The ICC test analysed the agreement between the recorded data from the first and second experiments. The ICC coefficient with 95% confidence intervals (CI) was calculated using a single-rating, absolute-agreement, 2-way mixed-effects model (Koo and Li, 2016). The relative TEM test analysed the differences. The relative TEM, a variation index, was calculated using the TEM method (Goto and Mascie-Taylor, 2007). The statistical significance was set at $P < 0.05$. The software package used for data analysis was PASW Statistics for Windows, Version 18.0 (SPSS Inc, Armonk, NY).

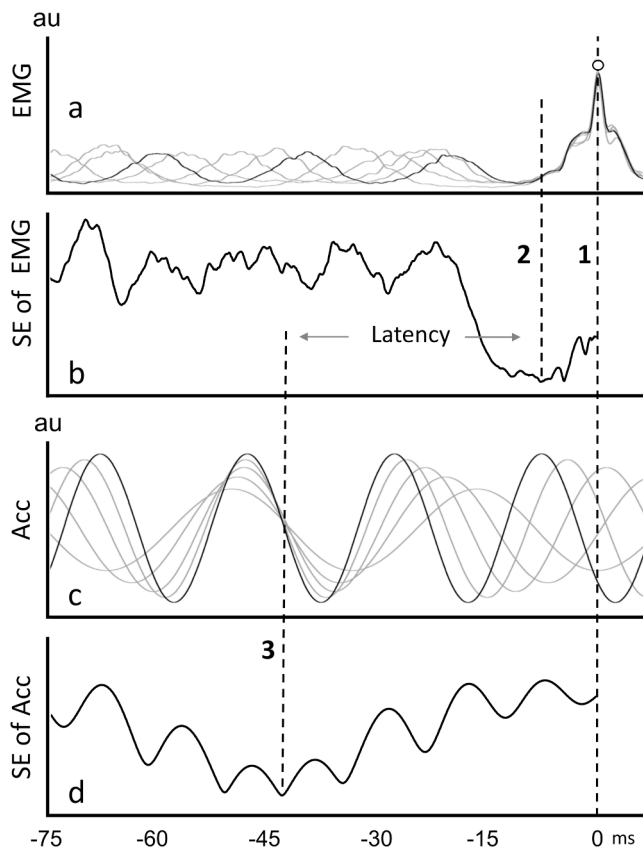


Fig. 1. Estimation of the effective stimulus time (EST) point. a. Five averaged rectified EMG traces, each representing five different vibration frequencies. b. The S.E. curve of rectified EMG. c. Five averaged acceleration sinusoidal curves, each representing five different vibration frequencies. d. The S.E. curve of acceleration. The empty circle and Line 1 represent the peak of spikes of the rectified EMG as the trigger point. The spike peaks were used as triggers to average acceleration data and rectified EMG data from a -75 to $+15$ ms segment. Line 2 represents the lowest value on the S.E. curve for the EMG data, indicating the initiation of the EMG response to the vibration stimulus. Line 3 represents the S.D. curve's lowest value for the acceleration data, indicating the effective stimulus time (EST) point. S.E.: standard error.

3. Results

The mean reflex latency ($\pm$ S.D.) was $34.6 (\pm 4.8)$ ms in the first experiment and $34.3 (\pm 4.0)$ ms in the second experiment. The EST was $40.6 (\pm 4.9)$ ms in the first experiment and $40.4 (\pm 4.4)$ ms in the second, with $p > 0.05$ for both measurements.

The ICC coefficient with 95% CI for the EST points, estimated for the first and second experiments, was $0.988 (0.950-0.997)$, $p < 0.0001$. The relative TEM was 1.3 % for the EST points. Fig. 2 shows a correlation between the EST points estimated for the first and second experiments.

The ICC coefficient with 95% CI for the S.E. curve data obtained from the first and second experiments was $0.932 (0.930-0.933)$; Fig. 3, $p < 0.0001$. The relative TEM was 12.1 %.

The ICC coefficient with 95% CI for the cumulative averaging acceleration curve data obtained in the first and second experiments was $0.931 (0.929-0.932)$. The relative TEM was 1.2%.

4. Discussion

The present study aimed to test the reliability of the cumulated averaging method used to determine the EST point. Following this, the ICC and TEM methods tested the consistency between acceleration data obtained from the first and second experiments. The results have proved

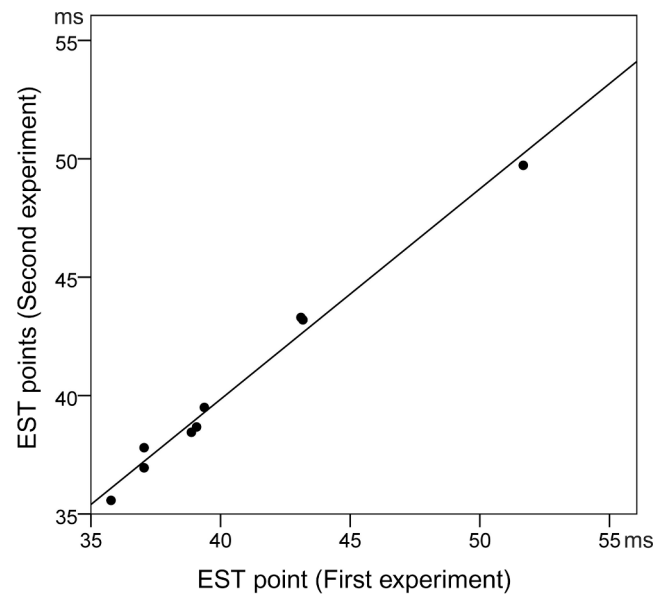


Fig. 2. Correlation between the EST points estimated for the first and second experiments.

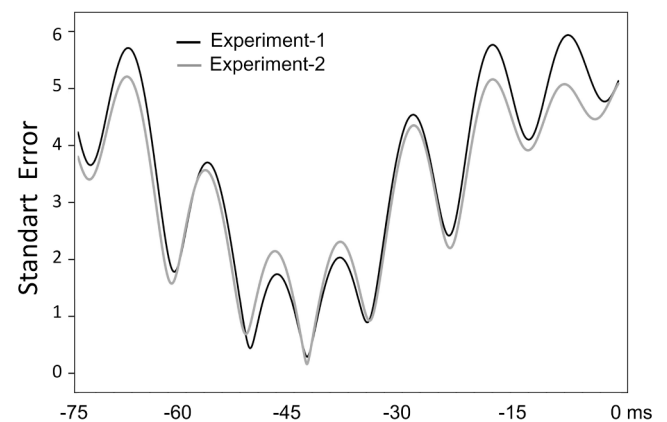


Fig. 3. Matching the standard error curves of the acceleration data obtained from the first and second experiments. Both curves are in a "V" pattern: S.E. decreases systematically between -75 ms and 0 ms. The point where the standard error is lowest indicates the EST point. The divergence between the two curves decreases as they approach the representative EST point. Blackline is the first experiment, and Greyline is the second experiment. Each curve is composed of 3000 bins.

that the cumulative averaging method is highly reliable in estimating the EST point of high-frequency vibration-induced reflex responses. This is because both intraclass correlation (ICC) and the technical error of measurement (TEM) showed significant matches between the results of the two experiments. Therefore, we reject our original hypothesis that the effective stimulation time point and error curves would differ.

The only other method available for estimating the reflex response latency using high-frequency vibration is that of the cumulant density function of Halliday and co-workers (1995). Their method uses peaks of signals to determine a lag time between two synchronously recorded signals. It reveals the signal relationship as a function of the lag time (Halliday and Rosenberg, 1999). However, this analysis does not provide a solution for determining the effective stimulus time and response onset points. This is because, although the cumulant density method effectively uses the peaks of signals to estimate the lag time, it does not indicate the exact time of the effective stimulus and the time of the initial response in the signal. Since the cumulative averaging method

provides this missing information essential to estimate the circuitry of the reflex response, and since the current study provided evidence for its high reliability, it would be helpful for other researchers who attempt to use high-frequency vibration in their research.

Mildren and co-workers (2017) used a different method (noisy tendon vibration) for the same purpose. They found that compared to the classical cross-correlation method, our previously published method (Karacan et al., 2014) and their method was more precise in indicating the earliest reflex-onset latency. They concluded that: “trigger averaging to either transient or sinusoidal stimuli could provide clearer identification of the earliest reflex-onset latency (mediated by the fastest conducting axons) compared with correlational techniques” (Mildren et al., 2017).

The EST point is determined on the averaged sinusoidal acceleration curve by calculating the standard error (S.E.) of acceleration data recorded during vibration at different frequencies. Therefore, the reliability of estimating the EST point using the cumulated average method depends on the average acceleration curve's repeatability and the lowest S.E. point on this curve.

4.1. Repeatability of the lowest S.E. Point

To test the reliability of the cumulated average method, the S.E. curves of acceleration data obtained from the first and second experiments were superimposed. As seen in Fig. 3, S.E. curves displayed a “V” pattern, where S.E. decreased systematically between -75 ms and 0 ms. The peak of the “V” pattern is where the S.E. was the lowest. The point where the standard error was lowest indicated the EST point (Karacan et al., 2014). Additionally, the divergence between the two S.E. curves decreased as they approached the peak of the V-pattern. The ICC statistics showed that the consistency between the two S.E. curves was very high. In parallel with these findings, the test–retest reliability of the cumulated average method used to estimate the EST point was high. In addition, the relative TEM statistics showed a minimal divergence between the EST points of the first and second experiments.

4.2. Repeatability of the cumulative averaging acceleration curve

The cumulative averaging acceleration curve plot technique has excellent reliability and low divergence. In the method used in this study, the location of the EST point on the cumulative averaging acceleration curve was shown with the help of the lowest standard error. The acceleration curves obtained from the first and second experiments were superimposed to test reliability. The fit of cumulative averaging acceleration curves obtained from the first and second experiments means perfect harmony of acceleration distribution traces consisting of thousands of data points.

A 75 ms acceleration data window consisting of 3000 bins was created by taking the rectified EMG spike peaks as triggers for each WBV frequency and acceleration curves as the source. These data windows were averaged for each frequency. Very high ICC and acceptable relative TEM values for the superimposed acceleration curves, high ICC correlations and the V-pattern of the S.E. curve imply that the cumulated average method indicates an EST point not by chance but with a high level of confidence.

4.3. Receptor of origin

High-frequency vibration stimulus can activate several receptors, including muscle spindles, Pacinian receptors and inner ear receptors. Among these receptors, muscle spindles' primary endings are exquisitely sensitive to high-frequency vibration (Brown et al., 1967; Matthews, 1976), which is probably why this receptor has been implicated as the receptor of origin on reflex responses using high-frequency vibration. However, in human studies, it is not easy to estimate the receptor origin to support such claims that used animal models (Cody et al., 1972) since

tendon organs and spindle secondaries were also implicated for responding to high-frequency vibration in experiments using micro-neurography (Fallon and Macefield, 2007). It is essential to find the reflex latency to gather evidence on the receptor of origin. Our cumulative averaging method is unique because it uses several different high-frequency vibration levels and accelerations to estimate the reflex latency. Since the current study provided evidence that the cumulative averaging method is highly reliable, and since the reflex latency we obtained is similar to the T-reflex latency (Aydın et al., 2020), we conclude that the receptors stimulated in the high-frequency vibration are likely to be the muscle spindle primary endings.

Limitations of the study.

The main limitation of the present study is that the reliability tests were performed only for the soleus muscle. Also, the EST point determined using the cumulative average method may contain a margin of error depending on the distance from the vibration platform of the muscle. Our previous study showed that this margin of error was approximately 0.14 ms for the gastrocnemius muscle and 0.25 ms for the rectus femoris muscle (Topkara et al., 2021). In light of the information above, it was estimated that the margin of error for the soleus muscle is negligibly low. However, the reliability of the cumulated averaging technique should also be tested for more proximal muscles.

5. Conclusions

The reliability of the methods used in reflex studies where the neuromuscular effects of WBV are examined is critical. Nowadays, there is no method other than the cumulated average to determine the exact time point (i.e., EST) when stimuli in continuous sinusoidal form, such as vibration, trigger a reflex response. This study has shown that the cumulated average method used to determine the EST point is highly reliable. We believe that with this confirmation, the cumulated average method will be widely used to study the threshold properties of receptors activated during vibration and the latency and duration of vibration-induced reflexes. Further studies are needed to test the cumulated average method's reliability for muscles other than the soleus, vibration amplitudes, subject positions, and other high-frequency sinusoidal stimuli.

Availability of data and material

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Funding

This research did not receive any specific grant from the public, commercial, or not-for-profit funding agencies.

ClinicalTrials.gov registration: NCT05129982 (11/08/2021).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

- Aydın, T., Kesiktaş, F.N., Baskent, A., Karan, A., Karacan, I., Türker, K.S., 2020. Cross-training effect of chronic whole-body vibration exercise: a randomised controlled study. *Somatosens. Mot. Res.* 37, 51–58. <https://doi.org/10.1080/08990220.2020.1720635>.
- Brown, M.C., Engberg, I., Matthews, P.B., 1967. The relative sensitivity to vibration of muscle receptors of the cat. *J. Physiol.* 192, 773–800. <https://doi.org/10.1113/jphysiol.1967.sp008330>.
- Çakar, H.I., Cidem, M., Sebik, O., Yılmaz, G., Karamehmetoglu, S.S., Kara, S., Karacan, I., Türker, K.S., 2015. Whole-body vibration-induced muscular reflex: Is it a stretch-induced reflex? *J Phys Ther Sci* 27, 2279–2284. <https://doi.org/10.1589/jpts.27.2279>.
- Cidem, M., Karacan, I., Dıraçoğlu, D., Yıldız, A., Küçük, S.H., Uludağ, M., Gün, K., Özkaya, M., Karamehmetoglu, S.S., 2014. A Randomised Trial on the Effect of Bone Tissue on Vibration-induced Muscle Strength Gain and Vibration-induced Reflex

- Muscle Activity. *Balkan Med J* 31, 11–22. <https://doi.org/10.5152/balkanmedj.2013.9482>.
- Cidem, M., Karacan, I., Cakar, H.I., Cidem, M., Sebik, O., Yilmaz, G., Türker, K.S., Karamehmetoglu, S.S., 2017. Vibration parameters affecting vibration-induced reflex muscle activity. *Somatosens. Mot. Res.* 34 (1), 47–51. <https://doi.org/10.1080/08990220.2017.1281115>.
- Cody, F.W., Lee, R.W., Taylor, A., 1972. A functional analysis of the components of the mesencephalic nucleus of the fifth nerve in the cat. *J. Physiol.* 226, 249–261. <https://doi.org/10.1113/jphysiol.1972.sp009983>.
- Fallon, J.B., Macefield, V.G., 2007. Vibration sensitivity of human muscle spindles and Golgi tendon organs. *Muscle Nerve* 36, 21–29. <https://doi.org/10.1002/mus.20796>.
- Goto, R., Mascie-Taylor, C.G.N., 2007. Precision of Measurement as a Component of Human Variation. *J. Physiol. Anthropol.* 26, 253–256. <https://doi.org/10.2114/jpa2.26.253>.
- Halliday, D.M., Rosenberg, J.R., Amjad, A.M., Breeze, P., Conway, B.A., Farmer, S.F., 1995. A framework for the analysis of mixed time series/point process data—theory and application to the study of physiological tremor, single motor unit discharges and electromyograms. *Prog. Biophys. Mol. Biol.* 64, 237–278. [https://doi.org/10.1016/s0079-6107\(96\)00009-0](https://doi.org/10.1016/s0079-6107(96)00009-0).
- Halliday, D.M., Rosenberg, J.R., 1999. Time and frequency domain analysis of spike train and time series data. *Modern Tech. Neurosci. Res.* 503–543 https://doi.org/10.1007/978-3-642-58552-4_18.
- Karacan, I., Saryıldız, M.A., Ergin, Ö., Özen, A., Karamehmetoğlu, S.S., 2009. Bone Myoregulation Reflex: a possible New Mechanism. *Nobel Med* 5, 9–17.
- Karacan, I., Cidem, M., Yilmaz, G., Sebik, O., Cakar, H.I., Türker, K.S., 2016. Tendon reflex is suppressed during whole-body vibration. *J. Electromyogr. Kinesiol.* 30, 191–195. <https://doi.org/10.1016/j.jelekin.2016.07.008>.
- Karacan, I., Cidem, M., Cidem, M., Türker, K.S., 2017. Whole-body vibration induces distinct reflex patterns in human soleus muscle. *J. Electromyogr. Kinesiol.* 34, 93–101. <https://doi.org/10.1016/j.jelekin.2017.04.007>.
- Karacan, I., Cakar, H., Sebik, O., Yilmaz, G., Cidem, M., Kara, S., Türker, K.S., 2014. A new method to determine reflex latency induced by high rate stimulation of the nervous system. *Front Hum Neurosci* 8, 536–536. 10.3389/fnhum.2014.00536.
- Karacan, I., Türker, K.S., 2020. Assessing reflex latencies in responses to vibration: evidence for the involvement of more than one receptor. *Manual Vibrat. Exercise Vibrat. Ther.* 135–142 https://doi.org/10.1007/978-3-030-43985-9_9.
- Koo, T.K., Li, M.Y., 2016. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J. Chiropr Med* 15, 155–163. <https://doi.org/10.1016/j.jcm.2016.02.012>.
- Matthews, P.B., 1966. The reflex excitation of the soleus muscle of the decerebrate cat caused by vibration applied to its tendon. *J. Physiol* 184, 450–472. <https://doi.org/10.1113/jphysiol.1966.sp007926>.
- Mildren, R.L., Peters, R.M., Hill, A.J., Blouin, J.S., Carpenter, M.G., Inglis, J.T., 2017. Frequency characteristics of human muscle and cortical responses evoked by noisy Achilles tendon vibration. *J Appl Physiol* 185 (122), 1134–1144. <https://doi.org/10.1152/jappphysiol.00908.2016>.
- Poshina, I.S., Adzhimolayev, T.A., Durinian, R.A., 1976. Influence of adequate stimulation on the impulse electrical activity of isolated frog muscle spindles [Article in Russian. *Neirofiziologiya*. 4, 426–433.
- Rittweger, J., Taiar, R., 2020. The Physics of Vibration In: *Manual of Vibration Exercise and Vibration Therapy*. Rittweger J (Ed) Print ISBN 978-3-030-43984-2, Springer Cham, Springer Nature Switzerland AG, Pages 3–22.
- Ritzmann, R., Mileva, K., 2020. Supraspinal Responses and Spinal Reflexes. *Manual Vibrat. Exercise Vibrat. Ther.* 121–133 https://doi.org/10.1007/978-3-030-43985-9_8.
- Scutter, S.D., Türker, K.S., 1998. Recruitment stability in masseter motor units during isometric voluntary contractions. *Muscle Nerve* 21, 1290–1298. [https://doi.org/10.1002/\(sici\)1097-4598\(199810\)21:10<1290::aid-mus7>3.0.co;2-6](https://doi.org/10.1002/(sici)1097-4598(199810)21:10<1290::aid-mus7>3.0.co;2-6).
- Sebik, O., Karacan, I., Cidem, M., Türker, K.S., 2013. Rectification of SEMG as a tool to demonstrate synchronous motor unit activity during vibration. *J. Electromyogr. Kinesiol.* 23, 275–284. <https://doi.org/10.1016/j.jelekin.2012.09.009>.
- Sowman, P., Brinkworth, R.S.A., Türker, K.S., 2006. Periodontal anaesthesia reduces common 8 Hz input to masseters during isometric biting. *Exp. Brain Res.* 169, 326–337. <https://doi.org/10.1007/s00221-005-0144-5>.
- Topkara, B., Aydin, T., Corum, M., Karaoglu, A., Ekici Zincirci, D., Bugdayci, D., Ones, K., Pakar, N., Kesiktas, N., Karacan, I., Türker, K.S., 2021. A new method to determine stretch reflex latency. *Muscle Nerve* 64, 726–733. <https://doi.org/10.1002/mus.27434>.
- Tucker, K.J., Türker, K.S., 2005. A new method to estimate signal cancellation in the human maximal M-wave. *J. Neurosci. Methods* 149, 31–41. <https://doi.org/10.1016/j.jneumeth.2005.05.010>.
- van Eijden, T.M.G.J., Brugman, P., Weijs, W.A., Oosting, J., 1990. Coactivation of jaw muscles: recruitment order and level as a function of bite force direction and magnitude. *J. Biomech.* 23, 475–485. [https://doi.org/10.1016/0021-9290\(90\)90303-k](https://doi.org/10.1016/0021-9290(90)90303-k).
- Yildirim, M.A., Topkara, B., Aydin, T., Pakar, N., Soy, D., Coskun, E., Ones, K., Bardak, A., Kesiktas, N., Ozyurt, M.G., Celik, B., Onder, B., Kılıc, A., Kucuk, H.C., Karacan, I., Türker, K.S., 2020. Exploring the receptor origin of vibration-induced reflexes. *Spinal Cord* 58, 716–723. <https://doi.org/10.1038/s41393-020-0419-5>.