Contents Lists is Available Online
International Journal of Motor Control and Learning (IJMCL)
Journal Homepage: www.ijmcl.com

History Dependence of Freely Chosen Index Finger Tapping Rhythmicity

Bente M. Nielsen[a], Camilla Fjordside[a], Nanna B. Jensen[b], Ernst A. Hansen[b]*

[a] Sport Sciences – Performance and Technology, Department of Health Science and Technology, Aalborg University, Niels Jernes Vej 12, DK-9220 Aalborg, Denmark.
[b] Associate Professor Sport Sciences – Performance and Technology, Department of Health Science and Technology, Aalborg University, Niels Jernes Vej 12, DK-9220 Aalborg, Denmark.

Keywords

Motor Behavior
Motor Control
Plasticity
Preferred Tapping Frequency
Rhythmic Movement

Ernst Albin Hansen
Email: eah@hst.aau.dk

Received: 2021/11/19
Accepted: 2022/02/12
Published: 2022/02/16

Abstract

Background: To test the following hypothesis. Initial submaximal tapping at preset relatively low and high target tapping rates causes a subsequent freely chosen tapping rate to be relatively low and high, respectively, as compared with a reference freely chosen tapping rate.
Methods: Participants performed three 3-min bouts of submaximal index finger tapping on separate days. In one bout (C, considered reference), the rate was freely chosen, throughout. In another bout (A), initial tapping was performed at a relatively low target rate and followed by freely chosen tapping. In yet another bout (B), initial tapping was performed at a relatively high target rate, followed by freely chosen tapping.
Results: At the end of bout A, the rate was 14.6±23.7% lower than the reference value during bout C ($p = 0.023$). At the end of bout B, the rate was similar to the rate during bout C ($p = 0.804$).
Conclusions: Initial tapping at a preset relatively low target rate caused a subsequent freely chosen rate to be lower than a reference freely chosen rate. The observation was denoted a phenomenon of motor behavioural history dependence. Initial tapping at a preset relatively high target rate did not elicit history dependence.

Introduction

Recently, a history dependence phenomenon in cycle ergometer pedalling was reported (Hansen et al., 2021). History dependence can refer to the fact that parts of the human physiology (e.g., one or a group of muscles, or the nervous system) and even functional aspects of the human (e.g., motor behavior or performance) depend on prior muscle activation (Hansen et al., 2021). Briefly, it was observed that the freely chosen cadence during a bout of submaximal pedalling depended on the preset cadence applied at the beginning of the same bout. Thus, initial pedalling with relatively low and high target cadences caused a subsequent freely chosen cadence to remain in the order of about 5% low and high, respectively, as compared with a reference freely chosen cadence (Hansen et al., 2021).

Other acute phenomena, which can be considered subordinate to history dependence, have been reported previously. As an example, steady-state isometric force at a preset muscle length is lower and higher after active shortening and active lengthening of a muscle, respectively (Abbott & Aubert, 1952; Herzog, 2004). Another example is that performance (e.g., of jumping) is enhanced after a conditioning exercise (e.g., in form of squats) (Young et al., 1998), a phenomenon denoted post-activation potentiation (Hodgson et al., 2005). A final example is that freely chosen tapping rate in a bout of index finger tapping is increased after a preceding tapping bout and a rest period (Hansen et al., 2015; Mora-Jensen et al., 2017), a phenomenon denoted repeated bout rate enhancement.

The motor activity of submaximal cycle ergometer pedalling at a freely chosen cadence is considered to be characterized as highly stereotyped and automated, as well as possible to maintain with negligible conscious attention (Hansen, 2015). Different activities, such as walking, running, swimming, and finger tapping, at freely chosen rate, share several of the mentioned rhythmicity-generation aspects with ergometer pedalling, although each activity is obviously distinct.

In order to investigate whether the mentioned phenomenon of motor behavioural history dependence of freely chosen cadence is unique to ergometer pedalling, the present study focussed on a different stereotyped rhythmic activity: finger tapping, which constitutes a simple and classic activity in motor control studies (Sardroodian et al., 2016; Shima et al., 2011; Teo et al., 2013; Wing & Kristofferson, 1973).

Therefore, the purpose of the present study was to test the following hypothesis. Initial submaximal tapping at preset relatively low and high target tapping rates causes a subsequent freely chosen tapping rate to be relatively low and high, respectively, as compared with a reference freely chosen tapping rate. A confirmation of the hypothesis would support that history dependence, as previously reported in pedalling, occurs in the obviously different motor activity of finger tapping, which still shares key characteristics of rhythmicity with ergometer pedalling.

Method

Subjects

A sample size estimation performed (www.biomath.info/power/prt.htm) in the design phase of the project resulted in 19 individuals. This estimation was based on paired t tests to be performed with an alpha value of 0.01 (set conservatively due to correction for multiple tests), an expected difference of 6 ± 7% (mean ± standard deviation), and a power of 0.80. Nineteen (10 males, 9 females) healthy and recreationally active individuals (mean ± SD: 1.75 ± 0.11 m, 73.2 ± 15.1 kg, 23 ± 3 years) participated in the study. None of the participants had any history of neural or musculoskeletal diseases. They were all informed not to consume coffee during the last 3 h before testing. In addition, not to consume alcohol during the last 24 h before testing. The participants were carefully informed about the procedures of the study and the overall aim ("to enlarge our knowledge about control of rhythmic movement"). At the same time, they were kept naïve to the specific purpose of the study. The reason was to avoid any particular conscious control of the tapping rate when this was freely chosen. All participants self-reported that they were right-handed. Written informed consent was obtained from the participants. The study conformed to the standards set by the Declaration of Helsinki and the procedures by The North Denmark Region Committee on Health Research Ethics.

Apparatus and task

The participant was seated and positioned at a table according to previously described details (Sardroodian et al., 2016), and all tapping was performed on a smartphone (Hansen et al., 2015) with the index finger of the right hand. In line with previous studies, a tapping bout lasted 180 s (Hansen et al., 2015; Sardroodian et al., 2016). Participants were blinded to information on tapping rate throughout all tapping in the present study.

Bout C consisted of 180 s of tapping at a freely chosen tapping rate. In order to do so, the participant was instructed to "tap in a relaxed and natural way and apply a preferred rhythm" (Hansen et al., 2020). It was emphasised that the tapping was neither supposed to be performed as fast as possible nor with as high a force as possible. Rather, it should be comfortable, and the participant was free to think about something else than the actual task during tapping. The rationale for this is that we were particularly interested in the non-consciously generated tapping rate, which is considered to be highly automated. In addition, there was no requirement of a steady rate through the bout.

Bout A consisted of 50 s of initial tapping at "a markedly lower tapping rate than the freely chosen tapping rate applied in bout C" followed by 130 s of tapping at a freely chosen rate (as in bout C). The participant was informed when the first 50 s had passed. As a result of this method, the relatively low tapping rate was individual and deliberately controlled by the participant. The relative duration and division of the time periods were inspired by a previous study with a similar purpose, however, using pedalling as motor activity (Hansen et al., 2021).

Bout B consisted of 50 s of initial tapping at "a markedly higher tapping rate than the freely chosen tapping rate applied in bout C" followed by 130 s of tapping at a freely chosen rate (as in bout C). As in bout A, the participant was informed when the first 50 s had passed. Again, as a result of this method, the relatively high tapping rate was individual and deliberately controlled by the participant.

Tapping was performed on an iPhone 10 (Apple Inc., Cupertino, CA, USA) installed with the app Tap Beats (version 1.3, Emidio Cunha), which counts the number of taps. The number of taps in every 15-s period was noted to allow for an evaluation of a possible alteration of tapping rate across time. Subsequently, the number from each 15-s period was timed by 4 to get the tapping rate in taps per min for each 15-s period.

Procedure

At the attendance, the participant was informed about the procedure. Instruction and physical demonstration of index finger tapping were performed by the test leader. No warm up or familiarisation were performed by the participant, in order to avoid repeated bout rate enhancement (Hansen et al., 2015; Mora-Jensen et al., 2017). Each participant reported to the test facility on three separate test days. Two weeks separated the three test days. Thus, the entire test period was four weeks for each participant. The justification for the two weeks separation is that fourteen days (Hansen & Ohnstad, 2008) and sixteen days (Hansen et al., 2015) have previously been reported to result in a stable baseline of the freely chosen tapping rate. For comparison, another study indicated that only seven days of separation between test sessions resulted in an increase of the freely chosen tapping rate from session to session (Sardroodian et al., 2016).

A single test session was performed at each of the three attendances. The test sessions consisted of an initial pre-set relatively low target tapping rate followed by a freely chosen rate (denoted bout A), an initial pre-set relatively high target tapping rate followed by a freely chosen rate (bout B), and a bout of index finger tapping at a freely chosen rate, throughout (bout C). Thus, a total of three different bouts were performed by each participant in this study. All participants performed bout C at the first attendance. The reason was that the target of the initial tapping rates in bout A and B were proportioned relatively to the freely chosen tapping rate in bout C, which was considered a reference rate. The other two bouts were performed in counterbalanced order. The participants were informed not to perform any finger tapping, besides the three bouts, during the entire test period (Fig. 1).

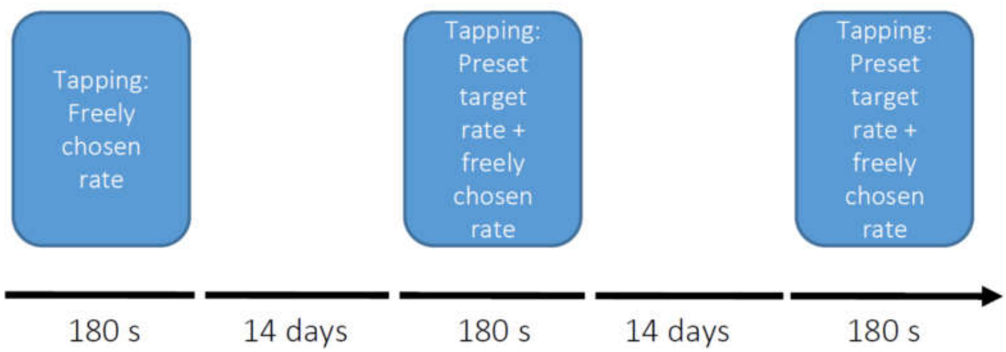

Figure. 1. An illustration of the design of the present study.

Note: All participants performed the first tapping bout at freely chosen tapping rate throughout (denoted bout C). The other two bouts consisted of initial tapping at a rate markedly lower than the freely chosen rate, followed by tapping at freely chosen rate (denoted bout A) - and at an initial rate markedly higher than the freely chosen rate, followed by tapping at freely chosen rate (denoted bout B). The order of the last two bouts was counter balanced among the participants.

Data analysis

Tests for normality (Shapiro-Wilks) were performed in IBM SPSS 25.0 (SPSS Inc., Chicago, IL, USA). These tests showed that $p > 0.05$, and the data were therefore considered normally distributed. Two-tailed paired Student's t tests were performed in Excel 2016 (Microsoft Corporation, Bellevue, WA, USA). Data are presented as mean ± SD unless otherwise indicated. Due to the design of the study, where data from two bouts (A and B) were systematically compared with data from bout C (considered a reference bout), $p < 0.025$ (i.e., 0.050/2 - family-wise Bonferroni correction) was considered statistically significant.

Results

The tapping rate as a function of time is presented in figure 2. It should be recalled that the time is divided into 15-s periods and there was a preset relatively low and high target tapping rate during the first 50 s of bout A and B, respectively. During bout A, the tapping rate during the last time period was lower than during bout C (p = 0.023), which was considered a reference. During bout B, the tapping rate during the last time period was similar to the reference value in bout C (p = 0.804).

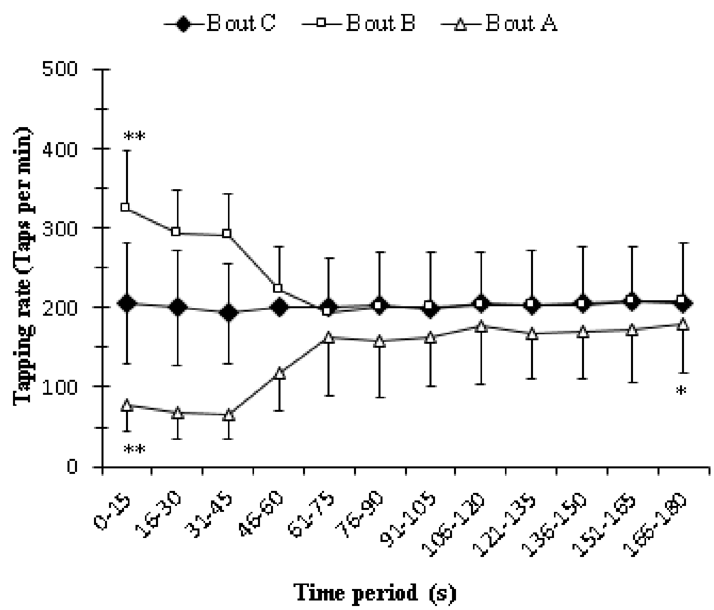

Figure. 2. Tapping rate as a function of time period during the three bouts of tapping.
Note: Data points represent mean values calculated across the group of participants. SD-bars are only shown in one direction for bout A and B. For bout C, SD-bars are only shown for the first three time periods. Altogether, for the sake of clarity. There was a preset target for the tapping rate during the first 50 s of bout A and B. Otherwise, tapping rate was freely chosen. *Different from bout C (p = 0.023). ** Different from bout C (p < 0.001). n = 19.

Figure 3 illustrates tapping rates at the beginning (panel A) as well as at the end (panel B) of the three bouts. A point of the figure is that it provides further insight into individual aspects of the motor behavioural responses. Thus, both individual data (coloured, with a distinct colour for each individual) and mean data (bold black dashes) of tapping rates are included in the figure. It is clear from the figure that all participants fulfilled our intention with the procedure, namely that the initial tapping rates in bout A and B should be lower and higher, respectively, than the initial tapping rate in bout C. Percentage wise, tapping rate at the beginning of bout A was 59.5 ± 16.6% lower than during bout C (p < 0.001). At the end, the tapping rate during bout A was still 14.6 ± 23.7% lower than during bout C (as stated above). During bout B, the tapping rate at the beginning was 77.8 ± 81.9% higher than during bout C (p < 0.001). At the end, however, the tapping rate during bout B was similar (+5.4 ± 40.3%, but non-significant, as stated above) to that during bout C.

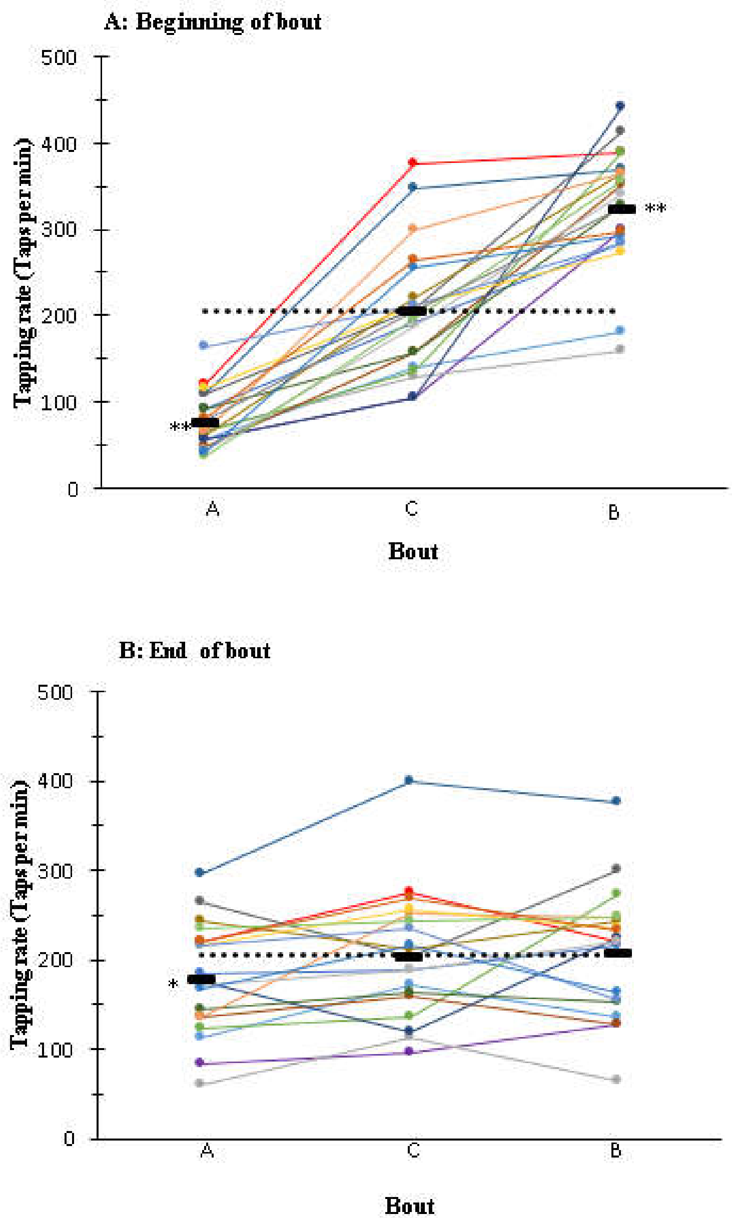

Figure.3. Tapping rate during the three bouts. Colored data points represent individual data.

Note: Each participant is represented by a separate colour (the same for both panels). Mean values calculated across all participants are presented by bold black dashes. A dotted line is drawn through the mean value from bout C, which may be considered a mean reference. Panel A contains data from the beginning of the bouts (value from the first 15-s period). Panel B contains data from the end of the bouts (value from the last 15-s period). **Different from bout C ($p < 0.001$). *Different from bout C ($p = 0.023$). $n = 19$.

Discussion and Conclusion

The basic freely chosen tapping rate, of about 202 taps per min, for the entire group of participants (grand mean in bout C), is similar to some previously published data from our laboratory (202 taps per min (Hansen et al., 2015)). At the same time, the present value is somewhat higher than other published values (163 taps per min (Mora-Jensen et al., 2017) and 167 taps per min (Hansen et al., 2020)) and lower than yet other data (245 taps per min (Hansen & Ohnstad, 2008)). The participants were not the same in all these mentioned studies. Still, the characteristics of the participants and the data collection methods were similar. Therefore, random between-sample differences are probably the reason for the differences.

The freely chosen tapping rate has been studied for test-retest reliability. In a study by Hansen et al. (2015), the within-session and between-day reliability of the freely chosen tapping rate were almost perfect (reflected by ICC-values above 0.80, (Landis & Koch, 1977)). Thus, ICC was 0.98 ($p < 0.001$) for freely chosen tapping rate in an initial bout versus a second bout performed 20 min later in the same test session. Furthermore, ICC was 0.94 ($p < 0.001$) for freely chosen tapping rate in the first bout in a test session versus the first bout in another test session performed 16 ± 4 days later. In addition, freely chosen tapping rate has been reported to be steady across a 12-week longitudinal period, with an average within-individual CI95 of 13 taps per min across individuals (CI95 ranged from 8 to 16 taps per min across individuals) (Hansen & Ohnstad, 2008).

The simple, submaximal, rhythmic, stereotyped motor output of index finger tapping has been suggested to be generated by spinal neural networks, termed central pattern generators (CPGs), in an interplay with supraspinal descending drive and sensory feedback (Hansen & Ohnstad, 2008; Shima et al., 2011). For completeness, it should be noted that the existence of CPGs in humans is difficult to conclusively prove. However, indirect evidence of their existence comes from, for example, studies on spinal cord-injured individuals (Calancie et al., 1994; Dimitrijevic et al., 1998) and infants (Yang et al., 1998). Further, based on a considerable amount of research, for the most part in non-human animals, it appears likely to be the case (Bucher et al., 2015; Grillner, 2009).

In the present study, the history of the tapping rate was altered deliberately. The intervention clearly revealed that the freely chosen tapping rate is history dependent – when initial tapping was performed at a preset relatively low rate. It appears doubtful that the history dependence of the freely chosen tapping rate in the present study should be the result of volitional motor control. Rather, the altered motor output rhythm is suggested to occur unconsciously. This is also in line with the suggested considerable spinal importance for the generation of the type of finger tapping applied.

It is not possible, based on the present results, to determine exactly what caused the history dependence phenomenon to occur. Still, mechanisms can be considered on a theoretical level based on evidence from animal experiments, which allow more invasive techniques to be applied. The observed unprompted alteration of the freely chosen tapping rhythmicity may be due to neuromodulation caused by the effect of neurotransmitter substances. Release of neurotransmitters can be elicited with supraspinal activation of the networks and as a result of sensory feedback. For an overview of neuromodulation of CPGs, the reader is referred to an excellent, previous review (Bucher et al., 2015). In another review article based on results from animal studies, it was also suggested that supraspinal input, as well as sensory feedback, have the potential to alter a CPG's net state of excitability (Fig. 1 in (Frigon, 2017)). Such neuromodulation may be due to the effects of excitation (Majczynski et al., 2020; Sanchez & Kirk, 2000) and inhibition (Miller, 2019) caused by neurotransmitters. Perhaps a reduced CPG-mediated freely chosen tapping rate, at the end of bout A, in that way was a result of net inhibition of the CPGs involved in the generation of the rhythmic motor activity due to the volitionally tamed motor activity at the beginning of the bout. As an alternative, the reduced freely chosen tapping rate might be a result of a reduced supraspinal descending tonic drive to the CPGs (De Luca & Erim, 1994). A combination of the two described scenarios could also have occurred.

Of interest, the present results obtained from finger tapping deviated to some extent from previous observations of a history dependent freely chosen cadence in ergometer pedalling (Hansen et al., 2021). Thus, while both initial preset low and high target cadences resulted in history dependence during pedalling, only a relatively low initial preset target tapping rate caused history dependence during finger tapping in the present study. The reason for this difference can only be speculated upon. However, cervical CPGs, which we presumed are involved in finger tapping, are considered to be more excitable than lumbosacral CPGs (Deliagina et al., 1983; Duysens & Forner-Cordero, 2019; Kiehn, 2006), which we presume are involved in pedalling. Perhaps a higher basic state of excitability of neural networks involved in the generation of finger tapping, as compared to pedalling, was the reason why freely chosen finger tapping rhythmicity was unaffected by an initial preset high target tapping rate. In other words, the absence of a difference between the final freely chosen tapping rate in bout B and C might reflect a kind of ceiling situation. It has been suggested that spinal neural networks can be considered to be balanced as a result of simultaneous increases in excitation and inhibition (Berg et al., 2019). The present results might reflect that such a balance of the involved networks was only tipped when the initial preset target tapping rate was relatively low, as in bout A. Regarding some alternative possible explanations for the observed results, it cannot be excluded that fatigue (in bout B) and an altered perception of the task to “tap in a relaxed and natural way and apply a preferred rhythm” (in the second part of bout A and B) might have played a role.

At the end of bout A, which began at a preset relatively low target tapping rate, the freely chosen tapping rate at the end of the bout was about 15% lower than the reference value of freely chosen tapping rate during bout C. For comparison, the previous pedalling cadence study (Hansen et al., 2021) showed only a 5% lower freely chosen cadence at the end of the bout, which began at a preset relatively low target cadence. However, it should be noted that initially in the present tapping bout A, the tapping rate was about 60% lower than in bout C. In the previous pedalling cadence study, the corresponding initial difference was less; namely about 31%. It is possible that the magnitude of the difference between an initial preset target movement rate and a reference freely chosen movement rate plays a role for the subsequent magnitude of history dependence.

A limitation of the present study is that all participants started with bout C and subsequently performed bout A and B (in counterbalanced order). Thus, an order effect cannot be entirely excluded. The reason for that particular design is the following. In a pilot experiment, we had individuals tapping at preset targets of relatively low (85 taps per min) and high (325 taps per min) rates by following a metronome. If the participants had been able to do that satisfactory, we could have counterbalanced bout A, B, and C. However, the pilot experiment showed that individuals were not able to follow the fast rate to a satisfactory degree. Furthermore, no tapping could be performed in advance of the test bouts in the present study - for example to determine the freely chosen tapping rate. Therefore, we found that tapping at low and high rates had to be performed relative to an experienced and sensed freely chosen tapping rate (in bout C), as it was done in the present study.

In conclusion, initial submaximal tapping at a preset relatively low target tapping rate caused a subsequent freely chosen tapping rate to be on average about 15% lower, as compared with a reference freely chosen tapping rate. The observed tapping rate behavior was denoted a phenomenon of motor behavioral history dependence. For comparison, initial tapping at a preset relatively high target tapping rate did not elicit history dependence.

Conflict of interests

The authors have no conflict of interests.

Acknowledgements

Mikkel E. Pedersen is thanked for his contribution to the study design, data collection, data analysis, and data interpretation. The participants are thanked for their effort.

References

1. Abbott, B. C., & Aubert, X. M. (1952). The force exerted by active striated muscle during and after change of length. J Physiol, 117, 77-86.
2. Berg, R. W., Willumsen, A., & Lindén, H. (2019). When networks walk a fine line: balance of excitation and inhibition in spinal motor circuits. Curr Opin Physiol, 8, 76-83.
3. Bucher, D., Haspel, G., Golowasch, J., & Nadim, F. (2015). Central pattern generators. In: eLS. John Wiley & Sons, Ltd: Chichester.
4. Calancie, B., Needham-Shropshire, B., Jacobs, P., Willer, K., Zych, G., & Green, B. A. (1994). Involuntary stepping after chronic spinal cord injury. Evidence for a central rhythm generator for locomotion in man. Brain, 117 (Pt 5), 1143-1159. http://www.ncbi.nlm.nih.gov/pubmed/7953595
5. De Luca, C. J., & Erim, Z. (1994). Common drive of motor units in regulation of muscle force. Trends Neurosci, 17, 299-305. https://doi.org/0166-2236(94)90064-7
6. Deliagina, T. G., Orlovsky, G. N., & Pavlova, G. A. (1983). The capacity for generation of rhythmic oscillations is distributed in the lumbosacral spinal cord of the cat. Exp Brain Res, 53, 81-90. https://doi.org/10.1007/BF00239400
7. Dimitrijevic, M. R., Gerasimenko, Y., & Pinter, M. M. (1998). Evidence for a spinal central pattern generator in humans. Ann NY Acad Sci, 860, 360-376. http://www.ncbi.nlm.nih.gov/pubmed/9928325
8. Duysens, J., & Forner-Cordero, A. (2019). A controller perspective on biological gait control: Reflexes and central pattern generators. Annual Reviews in Control, 48, 392-400.
9. Frigon, A. (2017). The neural control of interlimb coordination during mammalian locomotion. J Neurophysiol, 117, 2224-2241. https://doi.org/10.1152/jn.00978.2016
10. Grillner, S. (2009). Pattern generation. Encyclopedia of Neuroscience, 487-494.
11. Hansen, E. A. (2015). On voluntary rhythmic leg movement behaviour and control during

pedalling. Acta Physiol, 214, Suppl S702, 1-18. https://doi.org/10.1111/apha.12529
12. Hansen, E. A., Bak, S., Knudsen, L., Seiferheld, B. E., Stevenson, A. J. T., & Emanuelsen, A. (2020). Contralateral Transfer of the Phenomenon of Repeated Bout Rate Enhancement in Unilateral Index Finger Tapping. J Mot Behav, 52, 89-96. https://doi.org/10.1080/00222895.2019.1592101
13. Hansen, E. A., Ebbesen, B. D., Dalsgaard, A., Mora-Jensen, M. H., & Rasmussen, J. (2015). Freely chosen index finger tapping frequency is increased in repeated bouts of tapping. J Mot Behav, 47, 490-496.
14. Hansen, E. A., Nøddelund, E., Nielsen, F. S., Sørensen, M. P., Nielsen, M. Ø., Johansen, M., Andersen, M. H., & Nielsen, M. D. (2021). Freely chosen cadence during ergometer cycling is dependent on pedalling history. Eur J Appl Physiol (E-pub ahead of print). https://doi.org/10.1007/s00421-021-04770-w
15. Hansen, E. A., & Ohnstad, A. E. (2008). Evidence for freely chosen pedalling rate during submaximal cycling to be a robust innate voluntary motor rhythm. Exp Brain Res, 186, 365-373.
16. Herzog, W. (2004). History dependence of skeletal muscle force production: implications for movement control. Hum Mov Sci, 23, 591-604. https://doi.org/10.1016/j.humov.2004.10.003
17. Hodgson, M., Docherty, D., & Robbins, D. (2005). Post-activation potentiation: underlying physiology and implications for motor performance. Sports Med, 35, 585-595. https://doi.org/3574
18. Kiehn, O. (2006). Locomotor circuits in the mammalian spinal cord. Annu Rev Neurosci, 29, 279-306. http://www.ncbi.nlm.nih.gov/pubmed/16776587
19. Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. Biometrics, 33, 159-174. http://www.ncbi.nlm.nih.gov/pubmed/843571
20. Majczynski, H., Cabaj, A. M., Jordan, L. M., & Slawinska, U. (2020). Contribution of 5-HT2 Receptors to the Control of the Spinal Locomotor System in Intact Rats. Front Neural Circuits, 14, 14. https://doi.org/10.3389/fncir.2020.00014
21. Miller, M. W. (2019). GABA as a Neurotransmitter in Gastropod Molluscs. Biol Bull, 236, 144-156. https://doi.org/10.1086/701377
22. Mora-Jensen, M. H., Madeleine, P., & Hansen, E. A. (2017). Vertical finger displacement is reduced in index finger tapping during repeated bout rate enhancement. Motor Control, 21, 457-467.
23. Sanchez, J. A. D., & Kirk, M. D. (2000). Short-term synaptic enhancement modulates ingestion motor programs of aplysia. J Neurosci, 20, RC85. https://www.ncbi.nlm.nih.gov/pubmed/10875940
24. Sardroodian, M., Madeleine, P., Mora-Jensen, M. H., & Hansen, E. A. (2016). Characteristics of Finger Tapping Are Not Affected by Heavy Strength Training. J Mot Behav, 48, 256-263. https://doi.org/10.1080/00222895.2015.1089832
25. Shima, K., Tamura, Y., Tsuji, T., Kandori, A., & Sakoda, S. (2011). A CPG synergy model for evaluation of human finger tapping movements. Conf. Proc. IEEE Eng. Med Biol Soc, 2011, 4443-4448. https://doi.org/10.1109/IEMBS.2011.6091102
26. Teo, W. P., Rodrigues, J. P., Mastaglia, F. L., & Thickbroom, G. W. (2013). Comparing kinematic changes between a finger-tapping task and unconstrained finger flexion-extension task in patients with Parkinson's disease. Exp Brain Res, 227, 323-331. https://doi.org/10.1007/s00221-013-3491-7
27. Wing, A. M., & Kristofferson, A. B. (1973). The timing of interresponse intervals. Percept Psychophys, 13, 455-460.
28. Yang, J. F., Stephens, M. J., & Vishram, R. (1998). Infant stepping: a method to study the sensory control of human walking. J Physiol, 507 (Pt 3), 927-937. http://www.ncbi.nlm.nih.gov/pubmed/9508851
29. Young, W. B., Jenner, A., & Griffiths, K. (1998). Acute enhancement of power performance from heavy load squats. J Strength Cond Res, 12, 82-84.