

Research paper

The effects of standing in tutorial group meetings on learning: A randomized controlled trial

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ABSTRACT

Background: Standing desks have been brought into the education environment to reduce sedentary behavior among students. The current study explored the effects of standing in tutorial group meetings on learning among undergraduate students.

Methods: Ninety-six participants were randomly allocated to a Sit or Stand group, with 2 h tutorial group meetings scheduled, once or twice per week, for nine weeks. Learning was analyzed using exam grades, concept maps, and tutorial interactions.

Results: Overall, the Sit and Stand groups did not differ from each other in terms of learning, measured through their exam, concept map, and the use of learning-oriented interactions.

Conclusion: Standing in tutorial group meetings neither enhanced nor compromised learning. Considering the health risks associated with prolonged sedentary behavior, offering standing tutorial group meetings to undergraduate students is a recommended solution to break up prolonged sedentary behavior and encourage more physical activity, while maintaining the learning performance of students.

1. Introduction

Standing desks have been brought into the education environment [1–3] to combat the detrimental effects of sedentary behavior on physical [4,5] and mental health [6,7]. Thus far, students have welcomed the introduction of these standing desks [8]. However, as Minges et al. [9] point out in their systematic review, there is insufficient research into the impact of using standing desks on learning in the academic setting. In this study, we explored the effects of standing during tutorial group meetings, focusing specifically on how learning is affected in undergraduate students.

Research into the underlying mechanisms that explain the effects of light physical activity, such as standing, on learning-related outcomes has produced mixed findings. Some studies hint at positive effects, with acute light physical activity increasing oxygenation in brain regions that are important for cognitive functions related to learning [10–13]. Other than increased cortical activation/oxygenation, Byun et al. [13] also reported that a short bout of light cycling led to better cognitive performance on a test of executive function (i.e., Stroop task) and increased self-reported arousal levels. Studies have also shown that repeated bouts, or chronic light physical activity, increase the release of neurotrophic factors that support neuroplasticity as learning occurs [14,15],

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with the positive effects of long-term physical activity on cognitive processes being more robust than single bouts of physical activity [16]. However, some theories propose that learning may actually be negatively influenced by light physical activity. The transient hypofrontality hypothesis [17], the capacity sharing model [18], and the central capacity sharing model [19] argue that the brain has limited metabolic resources to process sensory stimuli, sustain body posture and movement, and maintain autonomic functions. Accordingly, the sharing of metabolic resources between light physical activity and learning should negatively affect learning due to the fewer resources to sustain learning.

When translated into the actual measurement of learning, the few existing studies reported contrasting results. Both Hasegawa et al. [20] and Isip [21] measured mathematical performance during acute standing interventions. Hasegawa et al. found no significant effects on multiplication [20], while Isip reported an improved performance on a mathematics exam [21]. The same inconsistent results hold for cognitive control functions, which were measured after the long-term use of standing desks. After 11 weeks, Wick et al. reported no significant effects [22], while after 28 weeks, Mehta et al. reported enhanced cognitive control [23]. If standing desks are to be used in classrooms, then further research is needed to understand how learning may be affected, research that controls for confounding variables and mimics actual learning in the field setting over the long-term. In the current study, we introduced standing desks to tutorial group meetings that were part of a bachelor's course and used the course exam as our first measure of learning. Considering the possible positive effects found from the studies that measured learning, we hypothesized that standing in tutorial group meetings leads to better exam performance (H1).

It is important to note that exams only provide an indirect measure of the actual process of learning. It is common for students to study intensely prior to their exam, motivated primarily by the desire to obtain good grades [24]. Exam grades may therefore reflect rote learning to score better exam grades, with the memorized information easily forgotten in the long term [25]. As Knight puts it: "The degree to which what is learned may be transferable depends very much on the learning processes, about which grades and degree classes are usually silent" [26]. Therefore, we studied the learning process in more detail. From a cognitive perspective, learning is the formation, transformation, and/or activation of one's cognitive representations as a result of external information [27]. Jean Piaget pioneered the constructivist-based approach to learning, positing that information from the environment interacts with the student's prior knowledge, shaping their cognitive structure of the concept being learnt [28]. Meaningful learning is said to have occurred when students integrate novel concepts with their prior knowledge to alter their pre-existing cognitive structures [25]. With regards to the effects of light physical activity, Liu and colleagues [29] found that participants who were learning a second language while lightly cycling performed better than their sedentary counterparts, showing enhanced vocabulary-learning from the onset of the longitudinal intervention. This enhanced learning carried over to the un-trained comprehension of sentences that improved exponentially with time, suggesting that the cognitive structures of these participants were changing with time, while being positively influenced by light physical activity. For the current study, we needed a method that would capture the changes of the cognitive structures as the students' learning progresses – and concept maps have been proposed as a powerful tool to visually display these changes [30,31]. Measured using concept maps, we hypothesized that standing during tutorial group meetings leads to better learning of academic concepts (H2).

Expanding on the constructivist approach, Lev Vygotsky argued that learning is socially constructed and develops through human interaction [32]. In an education environment, knowledge is socially constructed when the students engage in group discussions, such as interactions that occur in tutorial meetings. Learning in groups allows the students to share their knowledge and learn from others [33]. The students may challenge each other's ideas, either resulting in the justification of their

ideas and building confidence with respect to the learnt material, or resulting in the students realizing that their idea was invalid, therefore providing them with the opportunity to learn from other students' point of view [34]. One education model that applies social-constructivism as one of its core principles is problem-based learning (PBL). At Maastricht University [35], tutorial group meetings are based on PBL, where students are provided with academic problems in tutorial groups, and try to solve these problems in order to learn in a meaningful way. Briefly, PBL tutorial group meetings begin with the *pre-discussion*, where students are given a new case. In their group, students share their prior knowledge on the case, brainstorm about ideas, and identify learning goals. Using these learning goals, the students disperse to research and study on their own. In the next meeting, the students conduct a *post-discussion* to discuss their findings [36]. Therefore, group interactions play a prominent role in the students' learning, in line with Vygotsky's social-constructivist approach to learning.

Within the PBL tutorial group meetings, Visschers–Pleijers and colleagues identified three types of learning-oriented interactions [37]. These are *exploratory questioning*, *cumulative reasoning*, and *handling conflicts about knowledge*. According to Visschers–Pleijers et al., the learning-oriented interactions are indicative of deep learning, as opposed to non-learning-oriented interactions, which are *procedural* or *off-task*. In relation to the use of standing desks, Knight and Baer argue that standing increases arousal levels and encourage people to share their ideas, leading to improved information elaboration, and consequently enhanced group performance [38]. Therefore, there are grounds to expect that in standing tutorial group meetings, students are stimulated to share more information and elaborate more on their thoughts by asking exploratory questions, building on each other's reasoning, and handling intellectual conflicts when they arise. This leads to our final hypothesis that the use of standing desks during tutorial group meetings improves group interactions, shown by the increased usage of learning-oriented interactions (H3).

To summarize, extant literature on acute and long-term light physical activity interventions have led to mixed results on learning-related outcomes. Furthermore, the measurement of learning requires a more in-depth study. Therefore, the aim of this study is to explore the effects of using standing desks during tutorial group meetings, i.e., a light physical activity intervention, on different aspects of learning among undergraduate students. We hypothesized that standing in tutorial group meetings improves learning performance, as measured by the students' exam grades (H1), their performance on the concept maps (H2), and the use of learning-oriented interactions in the tutorial group meetings (H3).

2. Methods

2.1. Design, setting, and participants

This study used an exploratory, longitudinal, and randomized controlled design, embedded in tutorial group meetings that were part of the *Human Genetics, Reproduction, and Prenatal Development* course (course code: BBS1005) in the first year of the Biomedical Sciences bachelor at Maastricht University. The PBL educational model is utilized within these tutorial group meetings. The tutorial group meetings ran for nine weeks, amounting to 13 scheduled meetings in the months of April – June 2018. All educational activities were in the English language. A detailed protocol of this study is reported elsewhere [39].

First-year students enrolled for the BBS1005 course, who had no chronic musculoskeletal complaints, were invited to participate. From 135 undergraduate students who expressed interest to participate, an independent administrative coordinator randomly recruited and proportionally allocated 96 students into a Sit or Stand group. The sample size of 96 was selected for practical reasons, as only four classrooms were allocated for this study. With each classroom accommodating a maximum of 12 students, the 96 participants were divided into four Sit

tutorial groups and four Stand tutorial groups. Two Sit tutorial groups and two Stand tutorial groups were scheduled for an 8:30–10:30 session, and the other four tutorial groups attended an 11:00–13:00 session. All tutorial group meetings were held on Tuesday and Friday mornings. This study utilized field settings – except for the administered intervention, the tutorial group meetings were scheduled and conducted as typical tutorial meetings.

Four tutors volunteered to participate in the study. All four tutors led one 8:30–10:30 tutorial group and one 11:00–13:00 tutorial group. For the tutors, if they had a Sit tutorial group at 8:30–10:30, then their next tutorial group was a Stand group, and vice versa. All four tutors were committed to their allocated tutorial group throughout the nine weeks.

After detailed briefing about the study, written and verbal consent was obtained from all participating students and tutors. From this point onward, we use the term “participant(s)” to refer to the participating students. Ethical approval was obtained from the Netherlands Association for Medical Education (NVMO) Ethical Review Board (file number 1030).

The classroom setting was similar for each group, except that the Stand groups had standing desks with chairs hidden underneath the desks, while the Sit groups were sitting on the chairs (see Fig. 1). At the start of every tutorial group meeting, the desks’ height was adjusted for an ergonomically comfortable posture.

2.2. Materials

Learning was measured using three outcomes: exam grades, concept maps, and the use of learning-oriented interactions in tutorial group meetings. The latter two measures (i.e., concept map and the use of learning-oriented interactions) were applied to two PBL cases that were well-established and used every year in this course. Case 1 was on *early embryonic development until blastocyst and gene regulation*, while Case 2 was on *limb development and apoptosis in development*. These two cases were provided in different weeks of the course.

2.2.1. Exam grades

All participants were seated during the 3 h course exam that was scheduled on the last weekday of the nine-week course. The course exam was constructed independent of the current study and included questions concerning the entire course content. With the participants’ permission, their exam grades were provided by the Board of Examiners at Maastricht University after the course was concluded.

2.2.2. Concept map

With regards to the concept maps, participants were first asked to freely recall keywords on both Case 1 and Case 2 and link the keywords related to one another. An example of a resulting concept map can be found in Fig. 2. The concept maps were administered at four time points per case, with the first measuring *prior knowledge*, the second measuring learning from the *pre-discussion*, the third measuring learning from the

post-discussion, and the fourth measuring *information retained* two weeks after the post-discussion. The answers from all participants, without participant information, were collected onto a separate document, and independently scored by two field experts, co-authors UVR and JLVB. By separating the scoring from individual responses, the experts were blinded to the participant information and group allocation. The scores of both experts were averaged per student. Each keyword was scored on a scale of 0 to 3, with 0 being not relevant/important to the case and 3 being very relevant/important. The scores for the keywords were aggregated per student and the number of relationships that correctly linked the keywords were also counted for each student. The keyword scores and number of correct relationships were then compared between groups and across time points (prior knowledge, pre-discussion, post-discussion, and information retained).

Follow-up subgroup analyses were planned for the concept maps. The Sit and Stand groups were further split into four subgroups: Sit-Sit, Sit-Stand, Stand-Stand, and Stand-Sit. The first posture depicts the learning context during the tutorial group meetings, and the second posture depicts the posture taken when answering the concept maps. This arrangement was consistent for every concept map throughout the entire study. This arrangement was made for two reasons: One, to check for acute and/or carryover effects. And two, to control for the effects of context-dependent memory [40,41], where participants are expected to perform better on the concept map if the context during learning (i.e., their tutorial group meeting) and recall (during the concept map) are the same. For the concept maps, by having half the groups switched to a posture that was opposite to the posture taken during the tutorial group meeting, this arrangement was expected to even out the effects of context-dependent memory, which we checked with subgroup analyses.

2.2.3. Tutorial interactions

Finally, learning was also measured with the use of learning-oriented interactions during the tutorial group meetings. The learning-oriented interactions were exploratory questioning, cumulative reasoning, and handling conflicts about knowledge [37]. Non-learning-oriented interactions were procedural, off-task interactions, silence, and miscellaneous. These interaction types are defined in Table 1. In a pilot study, participants reported feeling uncomfortable with video recording, therefore audio recording with the Philips DVT6010 (Speech Processing Solutions GmbH, Vienna) was used to collect data on the use of these interactions. Researchers were not present in the classroom during the recordings to allow the tutorial group meetings to be conducted as naturally as possible.

The tutorial recordings were transcribed verbatim by an independent transcribing company, with any information on the participants’ identities deleted. Group allocation for each transcription was encrypted prior to analysis to blind the researchers during the analysis process. Following Visschers-Pleijers et al.’s analysis of PBL tutorial group interactions [37], the transcriptions were broken down into units of analysis, defined as an expression from one participant on one topic



Fig. 1. (a) Example of a sitting classroom, and (b) a standing classroom.

List all the keywords that are related to “early embryonic development until blastocyst, and gene regulation”.

1. Early embryonic development
2. Blastocyst
3. Gene regulation
4. Zygote
5. Oocyte
6. Spermatozoa
7. Transcription
8. Translation
9. Fertilization
10. Cleavage
11. Morula
12. DNA accessibility
13. Gametogenesis
14. Ovulation
15. mRNA
16. Euchromatin
17. Heterochromatin
18. Histones

Please draw your Concept Map here:

Fig. 2. Example of filled-out concept map.

while using one communicative function. The units of analysis were then coded according to the definitions in Table 1. Three raters (HQC, PWMVG, and HHCMS) independently coded a randomly selected transcription of one hour achieving interrater agreement of 83.2%. The rest of the tutorial interactions were then coded by HQC. As individual speakers were not distinguishable from the audio recording, each tutorial group ended up being represented as one participant or observation.

2.3. Procedure

Recruitment and online briefing started two months prior to the study. During the first tutorial group meeting of the course, the students were briefed and gave their informed consent to participate. The participants then provided information on their demographical background and completed the first concept map for Case 1. After one week (when Case 1 was scheduled for the course), the tutorial pre-discussion of Case 1 was audio-recorded. The participants completed a second concept map after the pre-discussion. Three days later, the participants reconvened in

their next tutorial group meeting, during which their post-discussion of Case 1 was audio-recorded. A third concept map was administered after this post-discussion. Two weeks after the post-discussion, a fourth concept map was administered to measure information retained. This procedure is detailed in Fig. 3, and was repeated for Case 2, which was scheduled four weeks after Case 1. On the last Friday of the nine-week course, the participants attended the 3 h course exam.

2.4. Analysis

IBM SPSS Statistics for Windows (version 25.0, Armonk, NY, US) was used to perform statistical analyses, with statistical significance achieved with two-sided *p* values $\leq .05$. Bonferroni correction was used in cases of multiple testing. The demographical information of the sample was summarized using means (*M*), standard deviations (*SD*), and sample size (*n*). Group comparisons were made using the Mann-Whitney *U* test for age, one-way analysis of variance (ANOVA) for body mass index, and the chi-square (χ^2) test for the categorical variables of timing of tutorial

Table 1
Definitions for the different types of interactions [37].

| Learning-oriented interactions | |
|---------------------------------------|--|
| 1. Exploratory questioning | Questions used to build critically and constructively upon each other's arguments. Examples include open questions, critical questions that questions another's comment, verification questions to check one's own understanding, and questions on a previously given argument. |
| 2. Cumulative reasoning | Arguments used for co-constructing knowledge in a positive manner. Examples include statements, active reasoning, confirmation or acceptance of a previous utterance, or a disjunctive question that requests for a short answer. |
| 3. Handling conflicts about knowledge | Dealing with contradictory information. Examples include active reasoning that contradict a previous comment, evaluation of one's understanding of the problem, and disagreement or negation of a previous utterance. |
| Non-learning-oriented interactions | |
| 1. Procedural | Not a learning-oriented interaction. Used to organize the PBL topic, for example, appointment of chairperson for the discussions or reporting of learning goals. |
| 2. Off-task | Not a learning-oriented interaction. These interactions are irrelevant to the PBL topic. |
| 3. Silence | Although Visschers-Pleijers et al. classified silence as off-task, we decided to put <i>silence</i> into a category of its own. This is because although we do agree that silence could be off-task, another interpretation of silence is quiet contemplation or reading, which do reflect learning. However, because we cannot be confident that we have captured all silences (e.g., silences that are less than a second), we do not include <i>silence</i> in the interpretation of results. |
| 4. Miscellaneous | When an utterance is unintelligible, either because it is audibly unclear or incomprehensible within the context of the utterance, then it is labelled as <i>miscellaneous</i> . <i>Miscellaneous</i> interactions are deemed random errors, not included in the interpretation of results. |

group meetings, sex, first language, nationality, self-rated health, and self-rated fitness.

For exam grades, the Mann-Whitney *U* test (with effect size estimate, *r*) was used to compare exam grades between the groups. The exam grades were also dichotomized into pass (coded as 1) and fail (0), and compared between the Stand and Sit groups using the chi-square test, with odds ratio calculated based on the odds of passing to failing in the

Stand group against the odds of passing to failing in the Sit group.

For the concept maps, the keyword scores and the number of correct relationships were compared between groups and across time for each case. We expected a linear increase in performance from prior knowledge until the post-discussion, followed by a drop in performance when concept maps were administered two weeks after the case to measure information retained. In order to satisfy the linearity assumption of the linear models, the first three concept maps of each case (prior knowledge, pre-discussion, and post-discussion) were analyzed separately from the fourth concept map (information retained). Linearity for each model was checked using scatterplots. When non-normality was spotted using QQ-plots, square root transformation was used. Marginal models were used for the first three concept maps of each case (prior knowledge, pre-discussion, and post-discussion) to account for the correlations between repeated measures and the missing outcome data due to absence in class. An unstructured covariance type was selected for the repeated measures, as the temporal gaps between each time point were not linear. Using restricted maximum likelihood (REML) estimation, the fixed effects were derived from the groups, without any further random effects added to the model. If there were significant interactions between the groups and time points, post-hoc simple-effect analyses were used to compare between groups at each time point, with Cohen's *d* reported. As for the fourth concept map of each case, factorial ANOVAs (effect sizes reported with partial eta squared, η^2) were used to compare the concept map performance between the four groups.

Covariates were controlled for in the statistical models of the concept maps. Using Spearman's correlation, demographical variables that correlated significantly with the outcome variables (keyword scores and number of correct relationships) were added to the respective models. If demographical variables were related to any missing outcome data as revealed by logistic regression, then these demographical variables were added to the respective models as well. Self-rated physical health correlated strongly with self-rated physical fitness ($r = .607, p < .001$). Therefore, these two variables were combined as "self-rated physical health and fitness" to prevent multicollinearity. Follow-up subgroup analyses were carried out using the same statistical models (marginal models for the first three time points and ANOVA for the fourth), with the only change being that the groups were split into Sit-Sit, Sit-Stand, Stand-Stand, and Stand-Sit, as described in Section 2.2.2. Concept map.

With regard to the tutorial interactions, individual speakers were not distinguishable from the audio-recordings. Therefore, each tutorial group ended up representing one participant or observation. Using G*Power: Statistical Power Analyses for Windows, version 3.1.9.2 [42],

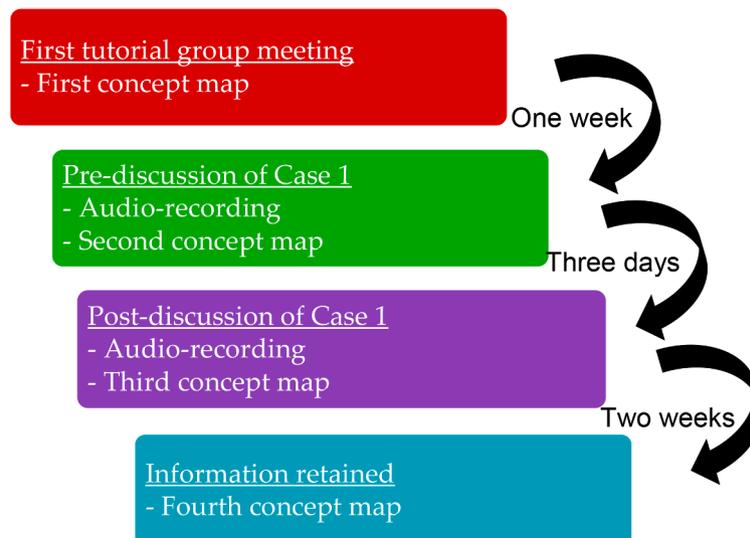


Fig. 3. Procedure for Case 1, repeated for Case 2 four weeks after the start of Case 1.

a post hoc power calculation was conducted ($\alpha = .05$, Cohen's $f = 0.20$). The resulting statistical power ($1 - \beta$) of 0.20 was determined to be weak. Hence, the tutorial interactions for each tutorial group were reported narratively. The four Sit groups were labelled Sit 1, Sit 2, Sit 3, and Sit 4, while the four Stand groups were labelled Stand 1, Stand 2, Stand 3, and Stand 4.

3. Results

3.1. Participant characteristics

As this intervention was part of the participating students' real tutorial meetings, class attendance varied across the measurement time points. Furthermore, four participants from the Sit group and three participants from the Stand group dropped out due to various reasons not related to the intervention. In addition, two participants from the Stand group dropped out from the study and were transferred to other concurrent tutorial groups that were not part of the study. As a consequence, the number of valid data points varied between 34 and 43 per group per time point (refer to Fig. 4).

The final sample consisted of 87 participants, who were 20 years old on average, with body mass index within a healthy range [43]. Furthermore, most participants self-rated themselves as having average

to above average health and fitness. There were more women than men participating in this study. With a majority of the participants being international students, most did not have English as their first language. The groups did not differ significantly with respect to their demographics (all p 's $> .05$, see Table 2).

3.2. Exam grade

As reported in Table 3, the average exam grade of the Stand group (6.5 ± 1.6 , on a 10-point scale) was higher than that of the Sit group (5.8 ± 1.6), but the difference between these scores only approached significance, $U = 1130.0$, $z = 1.80$, $p = .071$, $r = .20$. Similarly for passing grades (grades ≥ 5.5), although the odds of passing to failing was 2.05 times higher in the Stand group than in the Sit group, statistical significance was not achieved, $\chi^2(1) = 2.47$, $p = .177$.

3.3. Concept map performance

When completing the concept maps, the participants freely recalled relevant keywords to the case, and then linked the keywords that had a relationship with one another. For the first three time points of Case 1 (i.e., prior knowledge, pre-discussion, and post-discussion), there were significant interactions between group and time point for the keyword-

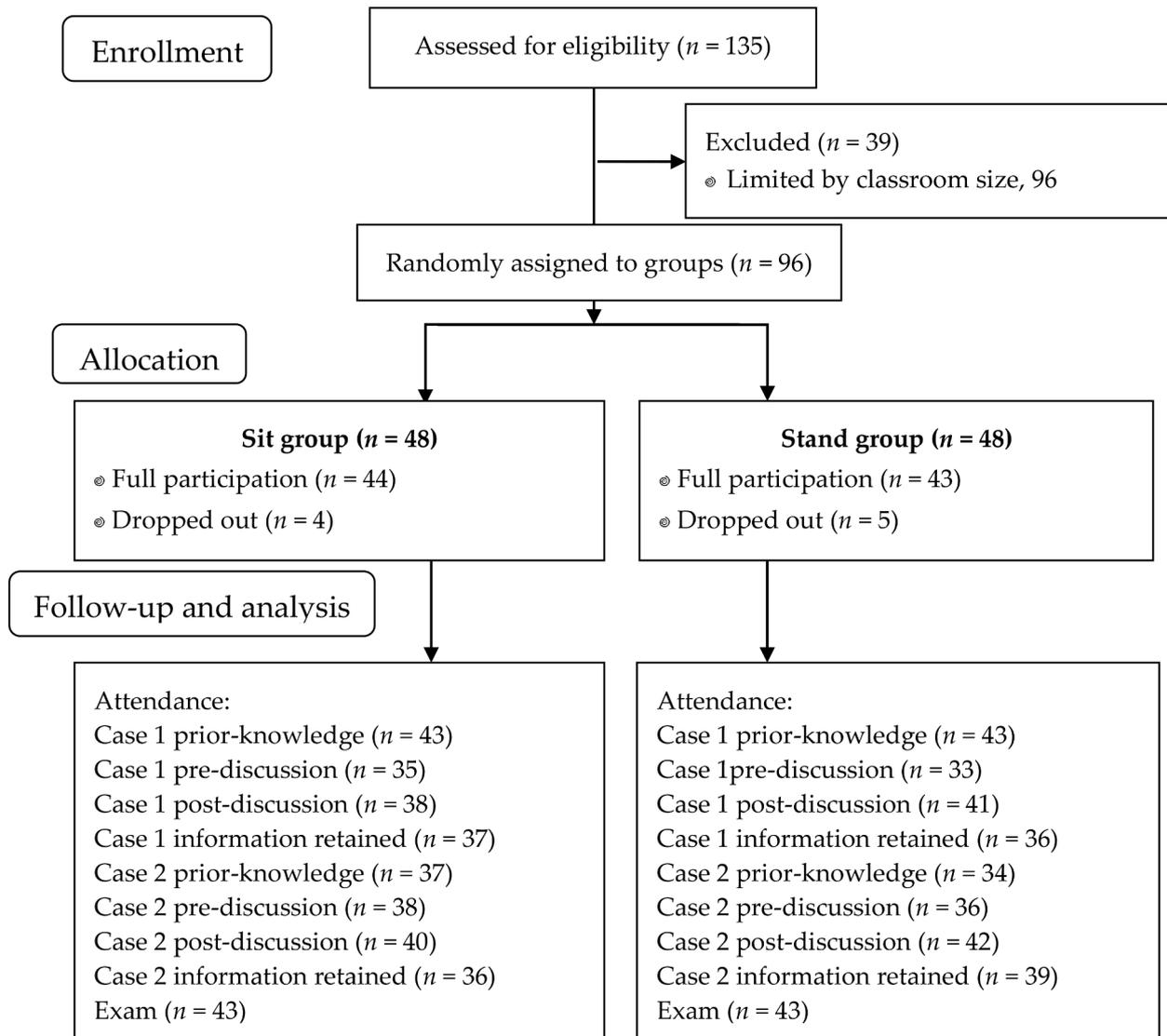


Fig. 4. XXXX.

Table 2
Self-reported characteristics of the final sample ($N = 87$), with group differences tested with Mann-Whitney U test (U), F -ratio test (F), or chi-square test (χ^2).

| | Total, $M \pm SD$ | Sit group, $M \pm SD$ | Stand group, $M \pm SD$ | Group differences |
|-----------------------------|------------------------------|-----------------------|-------------------------|----------------------------------|
| Sample size, n | 87 | 44 | 43 | |
| Age | 19.9 \pm 1.4 | 19.9 \pm 1.4 | 19.9 \pm 1.4 | $U = 937.0, z = -0.08, p = .939$ |
| Body mass index | 22.2 \pm 2.8 | 22.3 \pm 2.7 | 22.0 \pm 3.0 | $F(1, 85) = 0.19, p = .668$ |
| Tutorial meeting timing | $\chi^2(1) = 0.01, p = .914$ | | | Group differences |
| 8:30-10:30 | 44 | 22 | 22 | |
| 11:00-13:00 | 43 | 22 | 21 | |
| Sex | | | | $\chi^2(1) = 0.01, p = .932$ |
| Women | 53 | 27 | 26 | |
| Men | 34 | 17 | 17 | |
| First language | | | | $\chi^2(1) = 0.44, p = .506$ |
| English | 12 | 5 | 7 | |
| Non-English | 75 | 39 | 36 | |
| Nationality | | | | $\chi^2(1) = 0.28, p = .599$ |
| Local (Dutch) | 34 | 16 | 18 | |
| International | 53 | 28 | 25 | |
| Self-rated physical health | | | | $\chi^2(3) = 1.52, p = .677$ |
| Very poor | 0 | 0 | 0 | |
| Poor | 2 | 1 | 1 | |
| Average | 30 | 17 | 13 | |
| Good | 46 | 23 | 23 | |
| Very good | 9 | 3 | 6 | |
| Self-rated physical fitness | | | | $\chi^2(4) = 3.98, p = .409$ |
| Very poor | 2 | 1 | 1 | |
| Poor | 7 | 5 | 2 | |
| Average | 40 | 23 | 17 | |
| Good | 29 | 11 | 18 | |
| Very good | 9 | 4 | 5 | |

Table 3
Exam grade (mean \pm standard deviation) and number of participants passing and failing the exam.

| | Sit group | Stand group | Overall |
|-------|---------------|---------------|---------------|
| Grade | 5.8 \pm 1.6 | 6.5 \pm 1.6 | 6.1 \pm 1.6 |
| Pass | $n = 24$ | $n = 31$ | $n = 55$ |
| Fail | $n = 19$ | $n = 12$ | $n = 31$ |

scores ($F(2, 69) = 3.44, p = .038$.) and number of correct relationships ($F(2, 72) = 4.39, p = .016$). However, post-hoc simple effects analyses at each of the three time points showed no significant group differences (all p 's $> .05$, Bonferroni-corrected). As for the information retained two weeks after Case 1's post-discussion (analyzed separately, as explained in Section 2.4 Analysis), there were no significant group effects for the keyword-scores ($F(1, 59) = 2.78, p = .101, \eta^2 = .045$). However, there was a significant group effect for the number of correct relationships ($F(1, 64) = 5.42, p = .023, \eta^2 = .078$), showing that the Stand group had listed significantly more correct relationships compared to the Sit group.

As for the first three time points of Case 2, analysis of the keyword-scores yielded a significant interaction between the main effects of group and time point ($F(2, 77) = 3.24, p = .044$). Simple effect analyses showed that the Sit group had more prior knowledge than the Stand group for Case 2 ($p = .019, d = 0.60$). No other group differences were

found at other time points (all p 's $> .05$, Bonferroni-corrected). For the number of correct relationships of Case 2, the group and time point interaction was not significant ($p > .05$). The group effect on its own was marginally significant ($F(1, 77) = 4.02, p = .048$), but simple effect analyses did not find significant group differences at any of the first three time points (all p 's $> .05$, Bonferroni-corrected). For the final time point, that is, two weeks after Case 2's post-discussion, no significant group differences were found for keyword-scores ($F(1, 72) = 0.01, p = .920, \eta^2 < .01$) and the number of correct relationships ($F(1, 72) = 0.26, p = .611, \eta^2 = .004$).

Follow-up subgroup analyses were carried out to check for acute and/or carryover effects and the effects of context-dependent memory, with the Sit group split into Sit-Sit and Sit-Stand, while the Stand group split into Stand-Stand and Stand-Sit, as described in Section 2.2.2. Concept map. The findings are illustrated in Fig. 5, showing no group differences at most time points (p 's $> .05$), except for three instances in Case 1, which did not provide consistent support for acute and/or carryover effects, nor for context-dependent memory. No significant group differences were found in Case 2.

3.4. Tutorial interactions

The interactions of each individual tutorial group (four tutorial groups of the Sit group and four tutorial groups of the Stand group) are illustrated in Fig. 6. The Sit groups and the Stand groups do not appear to differ in their use of learning-oriented interactions, nor in their use of non-learning-oriented interactions. Some individual tutorial groups do show a distinct pattern (i.e., Sit 2 and Sit 4 tend to take more time during the post-discussions). Nonetheless, when the Sit and Stand groups were compared against each other, there were no obvious patterns to show that standing in tutorial group meetings lead to differences in tutorial interaction patterns. In the end, as statistical analyses on these visually-detected patterns were not possible, the interpretation of the tutorial interactions have to be taken carefully.

4. Discussion

The aim of this study was to explore the effects of standing during tutorial group meetings on learning in undergraduate students. The participants attended 2 h tutorial group meetings across nine weeks. Overall, we did not find support for the hypothesis that standing leads to enhanced learning, measured using exam grades, concept maps, and tutorial group interactions. Students who stood in their tutorial group meetings performed similar to their peers who sat in their tutorial group meetings. On average, the Stand group scored 6.5 on their exam (on a 10-point scale), while the Sit group scored 5.8, but the difference between these scores only approached significance ($p = .071$). Both groups had an overall similar performance in the concept maps. Finally, the interactions within the tutorial groups were similar. Using activity monitoring, we report elsewhere that the Stand group ended up spending less time per day being sedentary and more time being physically active [44]. While being more active, the current study reports that students in the standing tutorial group meetings were able to maintain a learning performance that was just as well as their peers who were sedentary.

Despite previous studies finding that light physical activity provides cognitive boosts [23,45] and physiological changes that can be beneficial for learning [10-15,38,46,47], standing in tutorial meetings did not have a consistent effect on learning, measured in this study using exam grades, concept map performance, and interactions used in the tutorial group meetings. Similarly, the current study does not provide support for the theories that suggest that there are fewer resources to sustain learning when the brain's limited resources are shared with the function of standing [17-19]. Although at some time points there were group differences found on the performance of the concept maps (e.g., number of correct relationships listed two weeks after the post-discussion of Case

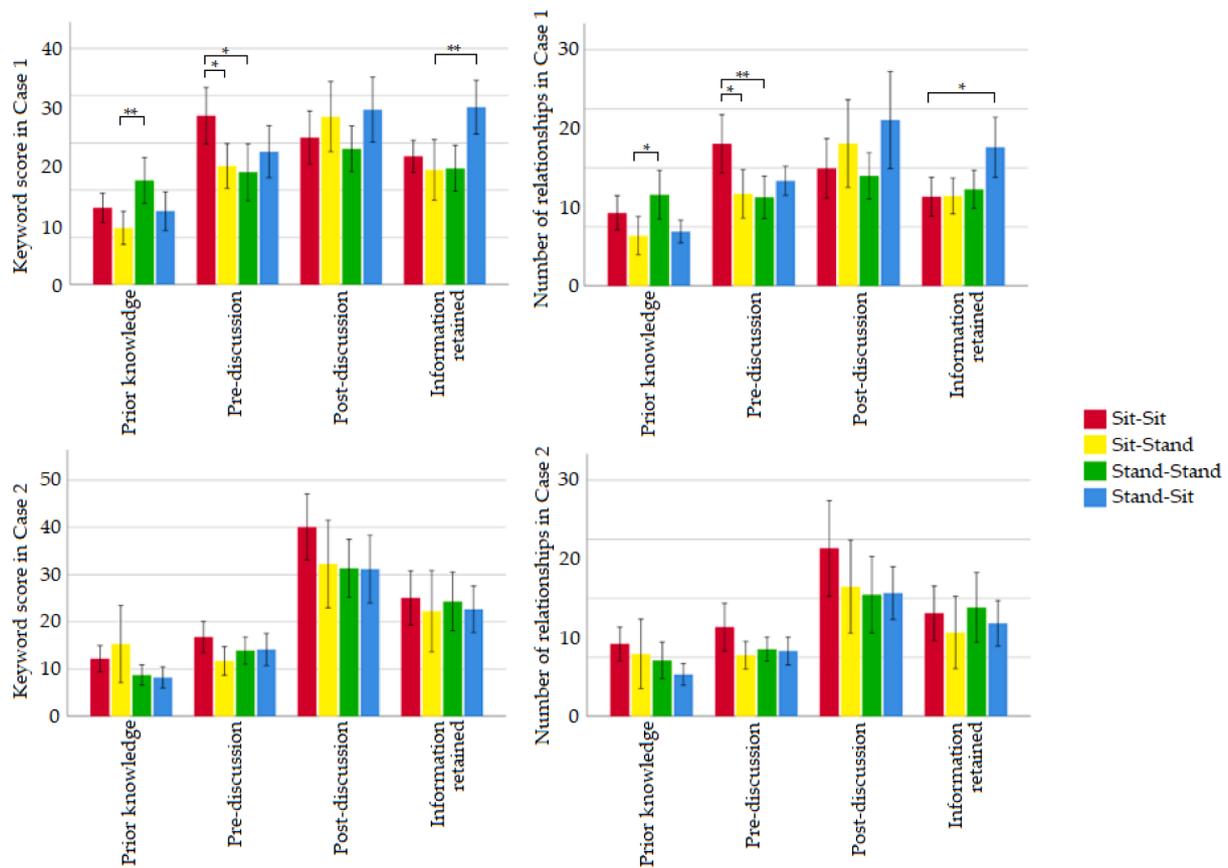


Fig. 5. Bar graph with 95% confidence interval error bars showing the learning progress of each group as illustrated by the keyword score and number of correct relationships in Case 1 and 2. Note. * $p < .05$; ** $p < .01$.

1), these findings were not replicated at other time points, suggesting a spurious effect. Reported in our protocol [39], an a-priori power analysis was conducted ($\alpha = .05$, Cohen's $f = .2$, statistical power of 0.95) to recruit a sufficiently large sample for comparing the groups on their concept map performance. Therefore, we do not expect for Type II error to explain for the concept map's overall lack of group differences.

The current study did not find support for any acute and/or carry-over effects, nor context-dependent effects. Despite previous studies reporting reliable context-dependent memory effects [40,41], the Sit-Sit and Stand-Stand groups who completed their concept maps in the same context as their learning did not consistently show better performance than the Sit-Stand and Stand-Sit groups, respectively. Hammond and colleagues [48] who studied the effects of standing and walking on memory performance also found no support for context-dependent memory, leading the authors to suggest that context-dependent memory is determined by the external environment, and not the internal, physiological changes induced by physical activity. According to this explanation, the students in the current study who stand while learning in tutorial group meetings should perform just as well in a seated exam as the students who sat while learning – a result that we indeed find in the current study.

An explanation for overall the lack of group difference is that the existence of various other factors that could have played a moderating role. For example, measuring learning during or after standing may influence the effects found [49,50], with positive effects generally found when testing is conducted after the light physical activity and negative effects generally found when testing is made during the light physical activity. Other potential moderators include the duration, type, intensity, and frequency of the light physical activity, individual differences, and type of outcome measure, which could all play a role in the strength and direction of effects found. It could be that the specific

learning outcomes measured in the current study were not influenced by increased light physical activity. Instead, outcomes that may have a more cognitive component (e.g., mathematical performance [21] and cognitive control [23] that have been reported to be enhanced by standing) may be more sensitive to the intervention. Another possible explanation for the lack of effect on learning is that the current intervention may not have induced the same physiological changes reported in other studies, some of which involved slightly higher-intensity physical activity interventions (e.g., light walking [12] and light cycling [10,13]). As the current study was not designed to disentangle the effects of these potential moderators, future studies may embark on such an endeavor. What we can reasonably conclude from the finding of the current study is that standing during tutorial meetings does not negatively affect the students' learning.

There are a few limitations to this study that need to be considered. First, we did not control for whether the students sat or stood during their own time outside of the tutorial classroom. Using accelerometry, we did measure the physical activity behavior of these students [44]. Although we did find that the Stand group ended up spending less time being sedentary and more time being physically active, we do not know specifically whether the students sat or stood during their self-studying, in preparation for the tutorial meetings. It is likely that all the students were sitting during their self-studying phase, diluting the effect of the standing tutorial meeting. A suggestion for future studies would be to account for the studying phase, for example, asking the students to note down their physical activity behavior (type and duration) while self-studying. A second limitation is that, sampling bias is a possibility, limiting the generalizability of this study. Considering that the participants voluntarily signed up for this study, the participants in this study may be more inclined to participate in light physical activity, or they may be more motivated as students. Furthermore, the repeated

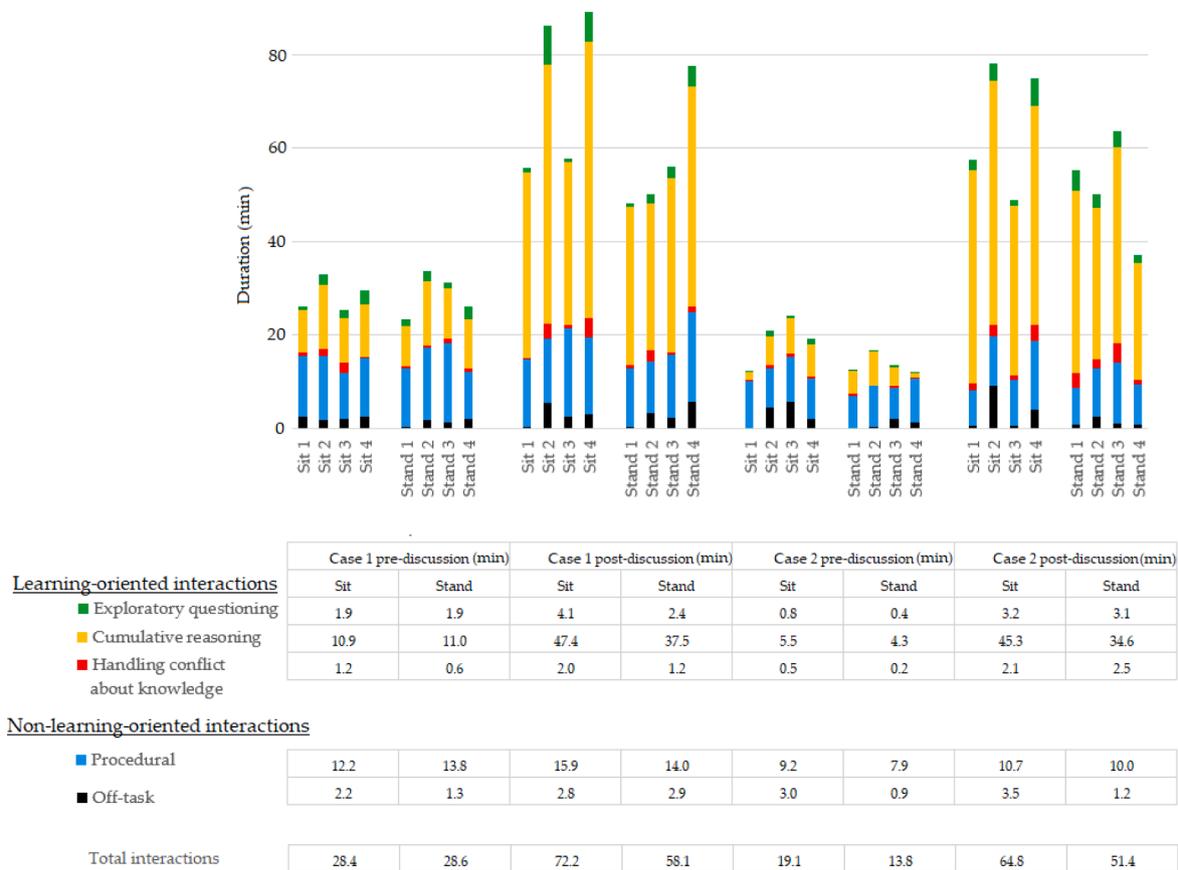


Fig. 6. Durations (minutes) for each interaction type used in individual tutorial groups are depicted by the bar graphs, while group averages are detailed in the table.

administration of concept maps may have induced a learning effect [51, 52], leading to exam grades that may differ from the rest of the non-participating cohort. Without the repeated administration of concept maps, the participants may have performed differently in their final exam. Therefore, the results of this study must be interpreted with caution, as the effect of the intervention may be different for the non-participating students. A final limitation is that, considering that the groups did perform differently in the first concept test of each case that measured prior knowledge, a pre-test on the students' baseline knowledge could have been used to adjust the exam grades accordingly.

The current study aimed to explore and generate an understanding of learning while standing in tutorial group meetings. A strength of this study is that the entire study was conducted within field settings over a period of nine weeks. This provided a realistic backdrop and enhanced ecological validity. Another strength is that various measures of learning were used (i.e., exam grades, concept maps, and tutorial group interactions) to examine learning as comprehensively as possible. Previous studies on the effects of standing in the education environment have primarily focused on behavioral changes [2,3], with the only study related to learning reporting no effects of standing on behaviors of academic engagement, such as active participation in class and attention [53]. The current study adds to the body of literature, providing a more comprehensive and direct insight on the learning process and its outcomes.

To conclude, the results of this paper suggest that undergraduate students who stand in tutorial group meetings learn just as well as their peers who sit in tutorial group meetings. We did not find support for the hypothesis that standing leads to enhanced learning. Reported elsewhere, we did find that the current intervention led to the Stand group adopting a more active and less sedentary lifestyle [44]. While being more active, students who stood in their tutorial group meetings achieved similar exam grades, similar concept map performance, and

similar patterns in their tutorial group interactions, compared to their more sedentary peers in the sitting tutorial group meetings. Therefore, we do encourage educational institutions, policy makers, and funding agencies to provide students with the option of a more physically active education. Standing tutorial group meetings are a recommended solution to reduce the risks of prolonged sedentary behavior while maintaining the students' performance on learning.

Declarations of Competing Interest

None.

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Availability of data and materials

All data collected were stored securely and only the primary researcher has access (via password and key) to the data. All personal information was encrypted with a code, to which the primary researcher only has the key. The encrypted data were stored separately from the main study data. After the data collection phase, all data were completely anonymized. Data generated from this study will be available on Dataverse.nl or on reasonable request via the corresponding author.

Author contributions

Study design: H.Q.C., R.H.J.E., and H.H.C.M.S.; Study pilot: H.Q.C. and R.H.J.E.; data collection, data analysis, data management, reporting of results: H.Q.C.; data scoring: U.V.R., J.L.V.B.; supervision, statistical planning, data analysis, reporting of results: R.H.M.D.G., P.W.M.V.G., M.G.A.O.E., R.H.J.E., U.V.R., J.L.V.B., and H.H.C.M.S. All authors have read and agreed to the published version of the manuscript.

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