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Low back pain in the marine training course: A study of incidence, risk factors, and occupational physical activity

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Abstract

Objectives: To evaluate the occurrence of LBP and LBP that limits work ability, to identify their potential early risks and to quantify occupational physical activity in Swedish Armed Forces (SwAF) marines during their basic four-month marine training course.

Design: Prospective observational cohort study with weekly follow-ups.

Participants: Fifty-three SwAF marines entering the training course.

Outcomes: Incident of LBP and its related effect on work-ability, and associated early risks. Occupational physical activity, as monitored using accelerometers and self-reports.

Results: During the training course, 68% of the marines experienced at least one episode of LBP. This yielded a LBP and LBP limiting work ability incidence rate of 13.5 and 6.3 episodes per 1000 person-days, respectively. Previous back pain and shorter body height (≤1.80m) emerged as independent risks for LBP (HR 2.5, 95% CI 1.4–4.3; HR 2.0, 95% CI 1.2–3.3, respectively), as well as for LBP that limited work ability (HR 3.6, 95% CI 1.4–8.9; 4.5, 95% CI 2.0–10.0, respectively). Furthermore, managing fewer than four pull-ups emerged as a risk for LBP (HR 1.9, 95% CI 1.2–3.0), while physical training of fewer than three sessions per week emerged as a risk for LBP that limited work ability (HR 3.0, 95% CI 1.2–7.4). More than 80% of the work time measured was spent performing low levels of ambulation, however, combat equipment (≥17.5 Kg) was carried for more than half of the work time.

Conclusions: Incidents of LBP are common in SwAF marines' early careers. The link between LBP and previous pain as well as low levels of exercise, highlights the need for preventive actions early on in a marine's career. The role of body height on LBP needs further investigation, including its relationship with body-worn equipment, before it can effectively contribute to LBP prevention.

Strengths and limitations of this study

- The present unique prospective study design with weekly follow ups that is conducted early on in the marines' careers is believed to have a strong potential to fill knowledge gaps in LBP epidemiology in marine regiments and similar military units.
- The use of a repeated time-to-event regression method, with discontinued risk intervals, better reflects the recurrent nature of LBP, and makes more use of collected data than methods using single time-to-first events as an outcome.
- The definition of a new episode of LBP used in the present study does not distinguish between a new "uniquely" first event and a "symptom flare up" from a recurrent chain of events, which is a problem seen in most studies on back pain or other musculoskeletal pain problems.

- The results for the two physical "max" tests of pull-ups and kettle-bell lifts are limited to male marines only, as no female marines performed these tests.

Keywords: Back pain, longitudinal, military, musculoskeletal disorders, musculoskeletal injury, occupational exposure, physical test, prevention, work ability, work exposure.

Background

Low back pain (LBP) is an epidemiological and clinical problem; it is the leading cause of disability worldwide (1). Its nature is commonly recurrent and causes reduction in physical activity (2) and work ability (3). Societal groups associated with high physical activity are indeed not spared musculoskeletal problems, and this includes highly trained military units. In fact, approximately 40% of Swedish Armed Forces (SwAF) marines on active duty experience LBP within a six-month period, and about half of these experience related limitations in work ability (4).

A high occurrence of musculoskeletal disorders is considered to be present by the SwAF occupational health personnel even during the four-month SwAF marine training course, where soldiers that have completed basic training are given their first marine-specific training. This physically demanding course focuses on marine-specific occupational tasks, including long range foot patrols with heavy equipment and assault operations from combat crafts (high-speed boats). Given the nature of this first and mandatory part of a marine's career, preventive measures at this stage could have a significant effect on the occurrence of future LBP in this group, and this has long been named a priority research topic in many military nations. Results gained from prospective studies in such communities, where occupational load and tasks are homogeneous and well known, have – we believe – great potential to fill knowledge gaps for further actions in defined military units.

Notably, medical examinations, health appraisals, and the evaluation of physical performance are basic routine procedures at the start of a military training course or before deployments. Information from such early examinations along with known risks from civilian contexts, such as a history of previous pain episodes (5, 6), physiological distress, or lifestyle factors (6, 7), has the potential to provide relevant risk information in operating activities. While low physical capacity and low performance on military physical fitness tests have previously been indicated as risks for LBP (8, 9), the screening of marines or similar elite units before entering the course with valid tests for their occupational exposures is not presently performed. New physical screening protocols have indeed been developed and introduced for other SwAF units, covering areas possibly related to the development of LBP in marines as well, for example lifting- and load-carrying capacities (10).

In addition, objective monitoring of occupational physical activity during the marine training course will aid in the interpretation of identified risks – such objective data has also been warranted for a long time. This study therefore aimed to prospectively evaluate the occurrence of LBP and its effect on work ability, as well as to identify potential early risks for such disorders in soldiers during the marine training course. Further aims were to quantify occupational physical activity and work-related exposure during the course.

Methods

Study design

This study used a prospective observational design with a cohort of SwAF marines entering the four-month marine training course. A screening program consisting of a self-administered questionnaire and a battery of physical tests was conducted at the start of the course, while pain occurrences were then followed up on a weekly basis. Occupational physical activity was continuously monitored with accelerometers worn during working hours for seven weeks of the course by a sub-cohort of participants; this was supplemented by platoon and individual logs of work tasks and physical training. All data collection was conducted at the 1st Marine Regiment, Stockholm, Sweden, between January and May, 2015. The study was approved in advance by the Regional Medical Research Ethics Committee, Stockholm (2014/1904-31/2). After receiving written and oral information on the study, signed informed consent was obtained from all participants prior to enrolment. Measurement occasions and the focus of the different phases of the course are illustrated in Figure 1, along with information on the participants' progression throughout the study.

Figure 1. about here

Patient involvement

Given the defined target group in the present study, no patients seeking medical care were recruited. The present research questions and outcomes are based on data/conclusions from our ongoing translational research on active duty marines (4, 11); it is also influenced from our empirical knowledge and clinical work in this population. The Marines' medical and occupational health services have taken part in planning the data collection, and they constitute the primary way of implementing the results in clinical work for the studied population.

Participants

To be eligible for inclusion in the present study, marines had to have the intention to complete the entire marine training course. Of 56 eligible marines, 53 met the criterion, and were enrolled in the study. The mean (SD) age, body weight, height, and body mass index for the enrolled marines were: 21.8 (3.4) years, 80.0 (10.1) kg, 1.82 (0.07) m and 24.1 (2.5) kg/m^2, respectively. The majority of participants (91%, n=48) were men. Ten (19%) had experienced pain in the lower back within six months prior to baseline. Marines with ongoing LBP at baseline lasting for five or more consecutive weeks adjacent to the course start (n=1) were excluded from analysis based on incidences.

Measurements and Procedure

Baseline questionnaires

Participants initially completed confidential questionnaires to elicit military and demographic background information (4), general health (12) and mental health (13), self-assessed work ability (12), and physical training habits. The questions, which are described in detail in Table 1, have previously been used in international and Swedish public health cohorts and studies of active duty SwAF marines. The questionnaires also included detailed information on musculoskeletal pain for nine anatomical areas (14) within the past week and six months, with the following reporting options: For pain within the past week *"No pain"* or *"Pain"* and for pain within the past six months *"No pain"*, *"Pain a couple a days per month or less",* or *"Pain a couple of days per week or more"*. Pain limiting work ability was assessed using the options *"Not limited"*, *"Limited to some extent",* or *"Limited to a large extent"*.

Table 1 about here

Physical baseline tests

Physical tests focusing on muscle strength and movement control were performed during the first ten days of the course. These tests, described in detail in Table 2, were selected on the basis of their use in clinical/preventive work among the studied population or in screening programs within the SwAF, and have previously been found reliable for use with active duty SwAF marines (19) or similar SwAF units (10). The strength tests, which were conducted following standardised SwAF instructions (10), were:

- *Kettlebell lifts* - The number of (correct) lifts of a pair of kettlebells (2 x 16, 24, or 32 kg) completed in a one-minute interval (10) and,
- *Pull-ups* - The number of (correct) pull-ups completed, performed hanging from a bar with an overhand (pronated) grip (10).

These tests were conducted within a series that also including a loaded lower limb functional test (20) (performed before these tests) and the ranger step test (21) (performed after these tests).

The two movement control tests were derived from the descriptions by Comerford and Mottram (22) and tested for good reliability in SwAFM (19). These tests focus on the ability to actively control or prevent compensatory movement in the lumbar spine, i.e. flexion, extension or rotation, while actively moving the lower extremities. The tests, conducted following standardised instructions, (19) were:

- *Double Leg Lift & Lower (DLL&L):* The subject, from a supine position, lifts both feet off the bench to a 90° hip flexion, and then lowers them back to the bench. Any uncontrolled movements in flexion or extension were recorded in the test protocol.
- *Double Leg Lift & Alternate Leg Extension (DLL&ALE):* The subject, from a supine position, lifts both feet off the bench to a 90° hip flexion, then lowers and straightens one leg to a fully extended position and then back to a 90° hip flexion. The procedure was then repeated with the other leg, after which both legs were lowered to the starting position. The direction of any uncontrolled movements in extension, flexion, or rotation was recorded in the test protocol.

Table 2. about here

Continuous assessment of work-related physical activity and occupational tasks

Twenty-seven marines from the inception cohort were randomly assigned by a computer-generated algorithm to wear accelerometers during the course. Six declined, leaving 21 marines in this sub-cohort. They were fitted with tri-axial accelerometers (GT3X+BT, Actigraph, Pensacola, FL) and instructed to wear them on the left hip during all working hours of the course, with the exception of planned prolonged loaded marches (due to the risk of interaction with back pack hip belts resulting in abrasions or compression injuries), aquatic physical training, or during training conducted at the marine combat obstacle course (due to water obstacles). They were also instructed to remove them during field exercises conducted at other bases during weeks 11-13 of the course due to an inability to collect data at these locations. The accelerometers were initialised using ActiLife software (version 5.5), with data sampling set at a rate of 30Hz. Information on occupational tasks and equipment worn, and physical training sessions conducted, was recovered from detailed weekly schedules completed by the instructing officers, as well as from the self-reported diaries kept by the marines.

Weekly follow-up

Incidence of musculoskeletal disorders and related effect on work ability were self-reported weekly during the course, using a short version of the baseline questionnaire. The number of responders for each week is illustrated in Figure 1. Weekly follow-ups were not strictly possible due to the geographic location of training during course week 12, so the follow up was conducted at the beginning of week 13 and reported as week 12.5 (i.e. week 12 and half of week 13).

Outcomes

LBP was defined as the occurrence of any self-rated pain in the lower back (from the twelfth ribs to the lower gluteal folds (23) within the preceding week, as reported during the weekly follow-up. LBP limiting work ability was defined as the occurrence of any self-rated pain in the lower back within the preceding week that had limited work ability.

For incidence proportions, rates, and regression analysis (described in detail below), marines were considered to be at risk for an event as long as they were under observation, and until the occurrence of a LBP event. At the time of pain occurrence, the risk interval was discontinued and marines were not considered to be at risk for a new episode until they were pain free for the next coming week (if reporting no pain in that week, it was counted, if reporting pain also that week, the week remained censored). Meeting this requirement automatically allowed them to re-enter the analysis (pain observation period). Marines with ongoing LBP at baseline were not considered at risk until they were pain free for at least one week, at which point in time they entered the analysis. Late entry was only allowed during the first four weeks to accurately reflect the independent variables collected at baseline.

Independent variables

Independent variables analysed as potential risk factors for LBP and LBP limiting work ability were selected based on existing evidence from active-duty SwAF marines, other military and civilian populations, and empirical knowledge from clinical work with the SwAF marines. These 17 variables, including two physical characteristics, four health-related, two work-related, three on physical training habits, and the results of the two strength and the two movement control tests (in flexion and extension), are described in detail in Table 1 and 2.

Confounding variables

Age, *BMI*, *sex*, *smoking*, *non-musculoskeletal co-morbidity,* and *LBP previously during the course* were a priori considered possible confounders. A confounder was defined as a variable that, when included during the analytic process, changed the hazard ratio of the crude regression model >20% (24).

Data management and statistics

Missing data

The dependent variables, i.e. LBP and LBP limiting work ability, were missing for 11% of the data due to subjects` lost to follow-up during the course. Also, of the independent variables, the kettle bells lift tests were missing for 30%, the pull-ups 23%, and the DLL-ALE test 4%, due to participants not being able (or allowed) to perform the test at baseline (illness such as having a cold or other infection in 44% of these and pain or similar co-morbidity in 56%). All female marines (n=5) missed the kettlebells lift and the pull-ups tests due to illness or ongoing pain. Analysis of the missing data mechanism (25) indicated, however, that data were missing completely at random for both outcome and predictor variables. Multiple imputations by Markov chain Monte Carlo, with random draws based on Jeffreys prior distribution, were used to generate 50 imputed datasets with completed data on all predictor variables, on which the pooled analyses were based (26). Given that no female marines performed the two strength tests, imputing values for females based on data from only male marines on these tests might affect the accuracy of the imputation. Therefore, regressions including these two tests were repeated, as part of the sensitivity analysis, on only complete cases, as well as on multiple imputed data with females excluded.

Descriptive statistics

LBP and LBP limiting work-ability

Weekly prevalence was analysed as a percentage of those under observation, with 95% CI (27). Weekly incidence of LBP and LBP limiting work ability was analysed as a percentage of those at risk, with a 95% CI (27). The incidence rate of LBP and LBP limiting work ability during the course was calculated based on the number of episodes and the time at risk, presented as episodes per 1000 person-days, with a corresponding 95% CI (28).

Work-related physical activity and occupational tasks

Accelerometer data were analysed only if sufficient wear time could be established, which was defined as at least 180 minutes of wear time per day (for full work days) on at least three workdays (for a five-day week). Non-wear time within days was identified by algorithms suggested by Choi (29). For valid wear-time, vertical counts per minute (cpm; where the arbitrary unit of counts is the filtered raw acceleration generated by body movements and captured by the accelerometer) - based on 10-second epochs - were extracted and reported as minutes and percentage of total work time, and work time per week spent in these predefined categories: 0-99; 100-2019; 2020-5998; and 5999- cpm (30). Here, the category of 2020-5998 cpm was considered to be comparable to slow to brisk walking (~3.8-7.5 km/h) (31, 32). In addition, the percentage of the workday spent in these categories was reported for time with and without load carriage (combat equipment, ≥17.5 Kg), as identified from the detailed schedules (verified against activity logs). Evaluation and comparison with work schedules were performed visually.

Regression analysis

We used the Andersen-Gill repeated time-to-event regression method (33, 34) with the robust sandwich variance estimator (35), and discontinuous risk intervals (34), as defined above, to examine the predictive association between the independent variables and LBP. The results are reported as hazard ratios (HR) with a corresponding 95% CI. Secondly, this method was applied to examine the predictive association between independent variables and LBP limiting work ability.

Independent variables were analysed in two blocks. First, *physical characteristics, work- and health-related* variables, as identified with univariate time-to-event regressions to be associated with the dependent variable, at the level of $p<0.25$, were included in a multivariable time-to-event regression model. This was followed by an iterative, purposeful selection process of deleting non-significant variables at $p>0.05$. The model was then refitted and verified until a final model contained only significant ($p<0.05$) independent variables, identified confounders, and significant ($p<0.05$) interactions (between independent variables in the final model and/or independent variables and confounders) (24). This process was repeated for the *clinical tests*, with the addition of the significant *physical characteristics, work- and health-related* risk factors addressed as additional potential confounders. All final models were deemed to have sufficient power, based on the events-per-variable ratio (36), and showed no violations of underlying assumptions of proportional hazards. Analysis was performed using STATA Statistical software (version 13.1; College Station, TX).

Results

Table 3 presents demographic and background data as well as self-rated general health for the 53 marines who completed the baseline questionnaire (96% response rate). Good or excellent current health status was reported by >95% of respondents. Of the 53 marines starting the course, 49% joined directly from basic military training, while the other 51% came from previous service in the SwAF or from a period of civilian occupation/studies.

LBP and LBP limiting work-ability

Figures 2 and 3 present the prevalence and incidence of LBP and LBP limiting work ability, expressed per week during the marine training course. A total of 68% of the marines experienced at least one episode of LBP during the course, of whom 57% reported related limitations in their ability to work. The average LBP episode consisted of 1.6 weeks of reported pain, with 42% of the sufferers experiencing at least one recurrent episode (with an average of 2.8 weeks without reporting pain between episodes). This gave an LBP incidence rate of 13.5 (95% CI 10.4 to 17.8) episodes per 1000 person-days. For LBP limiting work ability the corresponding incidence rate was 6.3 (95% CI 4.2 to 10.0). For comparison, incidence rates based on time to first event (during the course) are presented in supplementary Table 1.

Fig. 2 and 3 about here.

Risk factors for LBP and LBP limiting work ability

Individual physical characteristics, work- and health-related risk factors

Tables 4 and 5 present the results from univariate, final unadjusted and final adjusted multivariable recurrent-event regression models for LBP and LBP limiting work ability during the course. *Back pain (lumbar* and/or *thoracic back pain)* within six months prior to the MTC and *shorter body height (≤1.80m),* adjusted for the confounding effect of *sex* (LBP and LBP limiting work ability) and *previous neck shoulder pain* (LBP limiting work ability), were identified as independent risks. Additionally, *less than three sessions per week of physical training* was a significant risk for LBP that limited work ability. No interactions between the independent variables, nor with the confounders, emerged as significant in any of the models.

Tables 4 and 5 about here.

Clinical tests

Performing fewer than four pull-ups (HR 1.9, 95% CI 1.2–3.0), adjusted for confounding effect of *previous BP* and *body height*, was identified as a significant risk for LBP. However, no clinical tests were associated with LBP limiting work ability at $p<0.05$. Final unadjusted and adjusted models for LBP limiting work ability are presented in Supplementary Tables 2 and 3. Sensitivity analysis based on complete cases and imputed data, with only males, caused only marginal changes in the results, with no effect on inference.

Work-related physical activity and occupational tasks

Of the seven weeks of measurement, five contained sufficient wear time that could be fully used for analyses. During these weeks, an average of 16% of the working time (73 minutes per day) (not including long-distance march training, combat obstacle course or aquatic training, with a weekly average of additionally 2 hrs), was spent in physical activity of at least moderate intensity, i.e. 2020-5998 cpm, or slow-to-brisk walking (~3.8-7.5 km/h). On average, four percent of total working time was spent in physical activity of at least vigorous intensity, i.e. >5998 cpm. Sixty-one percent (44 min. per day) of the time spent in activities generating >2020 cpm was conducted wearing combat equipment (≥17.5 kg), as illustrated in Figure 4. There was, however, a large variation across weeks in work-time wearing combat equipment that spanned from 4% to 94%, as exemplified in Figure 5.

Discussion

This prospective cohort study among Swedish marines showed a high occurrence of LBP and consequent limitations in work ability while participating in their basic training marine-course. Marines with a history of previous back pain, shorter body height, or poor performance in the pull-up test were twice as likely to experience a new episode of LBP during this four-month period of physically demanding marine tasks.

This study followed 95% (n=53) of the participants enrolled in a typical marine training course in the Swedish Armed Forces (SwAF). Our cohort was homogeneous with regard to demographic characteristics and occupational tasks, which is similar to previous studies of marines (4), and may be regarded as a representative military-marine sample.

We believe this study to be the first to use a repeated time-to-event regression method, with discontinued risk intervals, for LBP in a military population. This method may – we believe – better reflect the recurrent nature of LBP and make more use of the collected data than the conversional methods using time-to-first event. The definitions of a new event vary between studies (37), but a pain-free period of one week was considered sufficient for an additional event to be defined as either a new event or symptom "flare up" (38) from a previous event. Regarding our baseline testing, marines that were injured (n=9) or ill (n=7) were not allowed to perform the "max effort" tests, because of the risk of worsening their health. However, analysis based on complete cases, as well as on imputations including only males, did not change the results, indicating an appropriate inference from the present results. Due to none of the female marines conducting the two "max" tests of pull-ups or kettle-bell lifts, these results should only be extended to males.

Our results show a relatively high incidence of LBP in this cohort of young marines, with more than two thirds experiencing at least one LBP episode during the course. This is almost twice the reported six-month LBP prevalence for active duty SwAF marines (4), more than twice the LBP incidence in the British combat infantryman's course (39), and higher than the total musculoskeletal injury incidence in other military training cohorts (40-42). This difference in pain occurrence may partly be explained by differences in the length of follow-up periods (43), or how LBP was defined (44). However, the recall period in this study was relatively short, and as such should limit the risk of recall bias. Given that three of five marines experiencing LBP also reported related limitations in work ability, it is likely that LBP reduced the intended goals with the course, and this may have future negative effects on the operational readiness of SwAF marine units.

Although previous musculoskeletal disorders are considered to be the strongest predictor for new musculoskeletal disorders in military populations (11, 41, 45, 46), it is not clear if such previous pain-episodes are anatomically region-specific in their prediction. This might not make a substantial difference in general primary prevention policy decisions, but the present findings could – we believe – help clinicians to be more specific in their selection of suitable secondary preventive measures for LBP. However, until the pathophysiological pathways between prior and future pain episodes are further disentangled, this does not inform the clinician what specific deficiencies to address. As such, the current use is limited to identifying persons at risk of LBP (47); marines at risk should be considered for further clinical examination and secondary preventive action. The same goes for marines with a body height of ≤1.80m, here identified as a risk for both LBP and LBP limiting work ability. While risks associated with body height are in line with our previous results (4), it is not likely that a short body height per se constitutes the actual risk, it could potentially represent an interaction with equipment worn or specific work tasks conducted.

The present results also highlight the need for regular physical training (≥ 3 sessions/week) for military personnel planning to attend the marine training course. This is in line with recommendations for general health in the civilian population (48), and should certainly be stressed for this physically active military community as well. Here, inferior upper-body strength, as tested by the pull-up test, seems to have played a role in back pain aetiology. This test, used in different forms in many military physical assessments (10, 49), is considered a relevant test of the ability to navigate over obstacles (10), but also as a proxy for general upper-body strength and muscle endurance (50). The test primarily challenges the back, shoulder and arm muscles, but also to a moderate extent the external oblique and erector spinae muscles (51). As such, it could represent a valid test for marines as upper body strength is crucial for load carriage (52). No female marines conducted these tests, therefore future cut-offs need to be validated for them. Neither the kettlebell lifts nor any of the movement-control tests predicted future LBP, however, “core-strengthening exercises” were already conducted as part of the marines’ daily calisthenics in this sample, potentially preventing such deficits early in the course. Still, the results tally with our previously reported results from active duty marines, where these tests, analysed as overall pass/fail, failed to predict back pain within a six- and 12-month event window (11).

While the physical demands of the course could be one reason for high LBP incidence, more than eighty percent of the work time measured was spent at low levels of ambulation, i.e. producing less than 2020 cpm. These results were similar to, or lower than, ambulatory movements reported for basic military training courses (53-55). However, in comparison with the US basic military training, where loads of no more than 4.5 kg were carried for 80% of the time (53), the marines in the present study carried combat equipment weighing >17.5 kg for more than half of the measured work time. In addition, the maximum weight of equipment worn on certain occasions, such as during loaded marches, can at times be more than twice that. Considering that both body-worn equipment and load carriage has been linked to LBP in deployed military personnel (8), this may possibly relate to the high LBP incidence in the present study. Furthermore, it highlights the need to consider load carriage when examining the association between ambulatory movement and LBP in the military context.

In summary, LBP and related limitations in work ability are common during the four-month physically demanding marine training course, and may affect the future operational readiness of marine units. Since previous LBP episodes are the most consistent risk for further LBP, marines entering the course with a history of LBP should receive tailor-made secondary preventive actions. Furthermore, marines with few weekly sessions of physical training, or with insufficient upper body strength, should be considered for targeted physical training. Further investigation on the role of body height on LBP is needed, including its relation to body-worn equipment, before it can be effectively used in LBP prevention. In addition, while ambulation was low for parts of the course, combat equipment was carried for more than half of the work time, further indicating the need to consider the role of body-worn equipment in LBP aetiology for this population.

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Contributorship statement

AM was the main writer of the paper and participated in the conception and design of the study, and acquired, analysed and interpreted the data. HL and HN participated in the conception and design of the study, planning of the analysis, interpretation of the data as well as the writing and revising of the paper. MD was involved in the design and planning of the study, as well as interpreting the data and revising the paper. As senior project researcher, BOÄ participated in the conception and design of the study, planning the analysis and interpretation of the data, and writing and revising the paper. All the authors have read and approved the final manuscript.

Competing interests

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Data sharing statement

No additional data are available.

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Tables

Table 1. Self-reported independent variables, the form in which they were included in regression analysis, procedures for retrieving the data and rationale for categorisation.

Independent variable	Reference	Exposure	Measurement procedure and variable management
Physical characteristics			
Body weight	Continuous		Body weight (in Kg) was self-reported and analysed as a continuous variable in the models.
Body Height	> 1.80m	≤1.80m	Body height was self-reported. Based on the hypothesis that being either "too tall or too short" may be negative for musculoskeletal health in this environment, as previously identified for this population (4), *body height* was initially categorised as ≤1.80m, 1.81-1.85m *(reference)* and ≥1.86m, but was reduced to a dichotomised variable due to no difference between the upper and the reference category being identified.
Rated health/health history			
Back Pain; within 6 mo. prior to course start	No	Yes	Self-reported musculoskeletal pain in the lower and/or thoracic back , defined as *"Pain a couple of days per month or less"* or *"Pain a couple of days per week or more"* within the past six months, analysed dichotomised as *yes* or *no* as previously for this population (4, 14).
Hip/Knee Pain; within 6 mo. prior to course start	No	Yes	Self-reported occurrence of musculoskeletal pain in the *hip* and/or *knee*, defined as *"Pain a couple of days per month or less"* or *"Pain a couple of days per week or more"* within the past six months, analysed dichotomised as *yes* or *no,* as previously for this population.
Neck/Shoulder Pain; within 6 mo. prior to course start	No	Yes	Self-reported musculoskeletal pain in the *neck* and/or *shoulder*, defined as *"Pain a couple of days per month or less"* or *"Pain a couple of days per week or more"* within the past six months, analysed dichotomised as *yes* or *no,* as previously in this population.
Mental distress	<4	≥4	The level of mental distress was captured by the General Health Questionnaire-12 (15), a

(GHQ-12 Score)			widely used screening instrument developed to detect "cases" of mental distress. It is a 12-question tool, summed up to give an overall score, ranging from 0 to 12, and a cut off of 4 points or more is considered an indication of clinically relevant mental distress (16). As such, "*Mental distress*" was categorised as ≥4 on the summary GHQ-12 scale.
Work related			
Current work ability with regard to best ever	≥9	<9	Self-rated work ability captured with the single item question from the work ability index (11). Current work ability was rated, with regard to ever best, on a 10-point ordinal scale. Based on the hypothesis that "less-than-optimal" work ability could constitute a risk in this environment, the responses were dichotomised as high (≥9) (*reference*) and moderate (<9).
Direct from basic military training (within 3 mo.)	No	Yes	Finishing basic military training within three months of the course start was considered a risk, due to the assumption that these soldiers had had less time to adapt to load carriage within the military. Therefore dichotomised as *yes* or *no (reference)*.
Physical training habits			
Physical training; sessions per week	>2 sessions /week	≤2 sessions /week	Average number of training sessions per week, exceeding 20 minutes, were rated on a five point ordinal scale as ≤1 day/week, 2 days/week, 3-4 days/week and ≥5 day/week. This item was derived (in addition to an increased number of maximum sessions) from items previously used in several public health cohorts in Sweden (17, 18). A U-shaped relationship with LBP was hypothesised for number of physical training sessions per week, i.e. too little and too much training may both be risks for LBP. Consequently, the training sessions per week variable was categorised as ≤2 session/week, 3-4 sessions/week (reference) and ≥5 sessions/week, but reduced to a dichotomised variable for LBP limiting work ability as no significant difference between the upper and reference category was found.
Muscular strength training; session per week	2-4 sessions /week	≤ 1 sessions /week ≥5	A U-shaped relationship with LBP was hypothesised for number of strength training sessions per week, i.e. too little and too much training may both be risks for LBP. Consequently *Weekly strength training* was categorised as ≤1 session/week, 2-4 sessions/week *(reference)* and ≥5 sessions/week.

		sessions /week	
Aerobic fitness training; sessions per week	>1 session /week	≤ 1 sessions /week	*Weekly aerobic training* was dichotomised as ≤1 session/week or >1 *(reference),* given two session per week a priori considered to be a realistic minimal amount of cardio vascular training necessary to maintain sufficient aerobic capacity during the physically demanding basic military training course.

Table 2. Physical test; independent variables, the form in which they were included in regression analysis, procedures for retrieving the data and rationale for categorisation.

Independent variable	**Reference**	**Exposure**	**Measurement procedure and variable management**
Strength tests			
Kettlebells lift; kg x repetitions	> 760	≤760	Pairs of kettlebells weighing 32, 24, or 16 kg each were used. The intended test weights were 2x32 kg, but subjects unable to perform the test safely with these loads could choose the lighter kettlebells. To make sure that the correct and safe lifting technique was used, all participants performed two test-lifts using a lower weight while being supervised by the test leader. The test measured the number of (correct) lifts of the weights performed in one minute. Based on the assumption that marines with the lowest lifting capacity are at greater risk of LBP, the lower tertile of the product of "numbers of lifts x weight lifted" was compared to the upper two tertiles (reference).
Pull-up; number of repetitions	≥ 4	≤ 3	Hanging from a pull-up bar, using an overhand grip with hands placed shoulder-width apart, the participants lifted their body until their chin was level with the bar. The number of (correct) lifts performed in one minute was recorded in the test protocol. The number of correct 'chins' is dichotomised as ≤3 or ≥4 *(reference).* Internationally, the cut-off for passing a pull-up test during

			yearly physical assessments for marines ranges from 3 (US marines) to 5 (Royal Marines) and as such, assuming that marines with the lowest pull-up capacity are at greater risk of LBP, the cut-off for the reference category was set at the median, ≥4 pull-ups (*reference*).
Movement control tests			*To make sure failure of any of the movement control tests was due to a "real" inability to control direction and not unfamiliarity with the test movement, all participants performed the test three to six times with feedback from the tester to ensure familiarisation. To monitor the movement of the lumbar spine, an air-filled pressure sensor (Pressure Biofeedback Unit, Chattanooga Group, Hixon, TN) was placed under the lower back.*
Double Leg Lift & Lower	pass	fail	The test assesses the ability to prevent extension and flexion of the lumbar spine (34). The subject, from a supine position, lifts both feet off the bench to a 90° hip flexion, and then lowers them back to the bench. Any uncontrolled movements in flexion or extension, defined as an ≥5mmHg change (from the starting pressure of 40mmHg), were recorded on the test protocol. Test performance on *flexion* and *extension* assessed in the tests was analysed as pass or fail.
Double Leg Lift & Alternate Leg Extension:	pass	fail	The test assesses the ability to prevent extension, flexion and rotation of the lumbar spine, and leg abduction, lateral rotation, and hip forward glide (34). The subject, from a supine position lifts both feet off the bench to a 90° hip flexion, then lowers and straightens one leg to a fully extended position and then back to a 90° hip flexion, before repeating the test on the other side. The direction of any uncontrolled movements, defined as ≥5mmHg change (from the starting pressure of 40mmHg), was recorded on the test protocol. Test performance for *flexion* and *extension* assessed in the tests was analysed as pass or fail.

Table 3. Demographic characteristics, physical characteristics and self-rated health at baseline.

	Mean	SD
Age (years)[a]	21.8	3.4
Body weight (kg)	80.0	10.1
Body height (m)	1.82	0.07
Body mass index (kg/m^2)	24.1	2.5
GHQ-12 Score	1.8	1.6
Muscular strength training; hours per week[a]	4.5	2.7
Aerobic fitness training; hours per week[b]	3.1	1.9
	%	**95% CI**
Smoking		
No	71.7	58.4-82.0
Occasionally	28.3	18.0-42.6
Yes	0.0	0.0-6.8
Snus (smokeless tobacco)		
No	64.2	50.7-75.7
Occasionally	11.3	5.3-22.6
Yes	24.5	14.9-37.6
Baseline testing	**Mean**	**SD**
Pull-ups	7.8	5.2
Kettlebell lifts		
Average lifts	17.6	6.4
Kettlebell, average weight (x2)	29.8	4.1
	%	**95% CI**
MCM-Tests, per direction;		
DLL-L Flex; Fail	19.2	10.8-31.9
DLL-L Ext; Fail	34.6	23.2-48.2
DLL-ALE Flex; Fail	19.6	11.0-32.5
DLL-ALE Ext; Fail	43.1	30.1-56.7

Note: Reported with mean and standard deviation (SD) or percentage and corresponding 95% Wilson Score confidence interval (95% CI).

[a]Average weekly hours of muscular strength training during previous six months (median (interquartile range) all; 4(3.5), males; 4(3.5), females 3(3)).

[b]Average weekly hours of aerobic fitness training during previous six months (median (interquartile range) all; 3(2), males; 3(2), females 5(3)).

Table 4. Regression analyses of individual physical characteristics, work- and health-related risk variables: univariate and multiple final adjusted[†] hazard ratio (HR) for low back pain (LBP) during the marine training course.

Variable	Univariate				Final Crude Multivariable				Final Adjusted Multivariable[a]			
	HR	**95% CI**		**P value**	**HR**	**95% CI**		**P value**	**HR**	**95% CI**		**P value**
Physical characteristics												
Body weight (kg)	1.01	0.99	1.03	0.441								
Body Height ≤ 1.80 (m)	1.48	0.84	2.58	0.172	1.73	1.03	2.92	0.040	1.98	1.19	3.29	0.009
Rated health/health history												
Mental distress (GHQ-12 Score)	2.08	0.65	6.70	0.219								
Back Pain; within 6 mo. prior to course start	2.00	1.09	3.64	0.025	2.26	1.27	4.03	0.006	2.47	1.41	4.31	<0.001
Hip/Knee Pain; within 6 mo. prior to course start	1.50	0.85	2.66	0.163								
Neck/Shoulder Pain; within 6 mo. prior to course start	1.63	0.91	2.90	0.098								
Work-related												
Current Work ability with regard to best ever	1.69	0.97	2.94	0.064								
Direct from basic military training (within 3 mo.)	1.08	0.62	1.91	0.779								

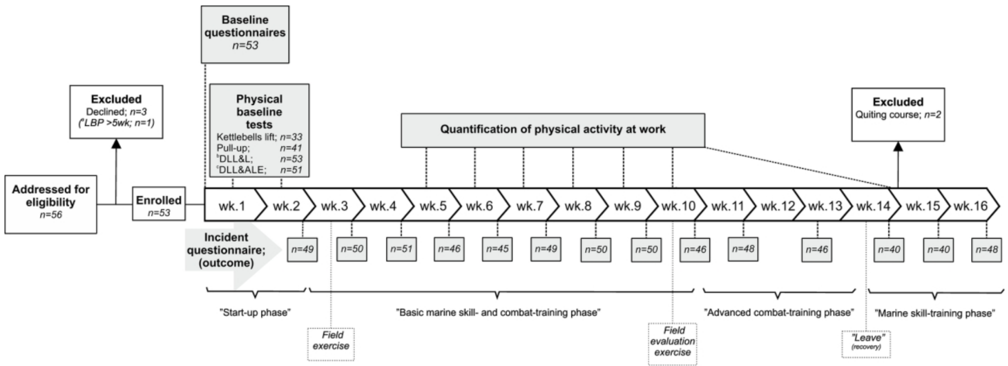
Table 4. cont.	Univariate				Final Crude Multivariable				Final Adjusted Multivariable[a]			
	HR	**95% CI**		**p value**	**HR**	**95% CI**		**p value**	**HR**	**95% CI**		**p value**
Physical training habits past 6 months												
Physical training;												
≤ 2 sessions//week	1.18	0.53	2.64	0.692								
3-4 sessions/week	1.00											
≥ 5 sessions//week	1.29	0.70	2.37	0.418								
Muscular strength training;												
≤ 1 sessions/week	0.90	0.52	1.54	0.690								
2-4 sessions/week	1.00											
≥ 5 sessions/week	1.27	0.58	2.78	0.542								
Aerobic fitness training;												
≤ 1 session/week	1.24	0.66	2.36	0.502								

[a] Adjusted for confounding effect of sex

Table 5. Regression analyses of individual physical characteristics, work- and health-related risk variables: univariate and multiple final adjusted[†] hazard ratio (HR) for low back pain (LBP) limiting work ability during the marine training course.

Variable	Univariate				Final Crude Multivariable				Final Adjusted Multivariable[a]			
	HR	**95% CI**		**p value**	**HR**	**95% CI**		**p value**	**HR**	**95% CI**		**p value**
Physical characteristics												
Body weight (kg)	1.00	0.96	1.04	0.991								
Body Height ≤1.80 (m)	2.20	0.96	5.03	0.062	3.04	1.35	6.86	0.007	4.48	2.01	9.97	<0.001
Rated health/health history												
Back Pain; within 6 mo. prior to course start	2.48	1.04	5.91	0.040	4.47	1.80	11.11	0.001	3.58	1.44	8.90	0.006
Hip/Knee Pain; within 6 mo. prior to course start	1.15	0.41	3.23	0.784								
Neck/Shoulder Pain; within 6 mo. prior to course start	2.79	1.18	6.57	0.019								
Work-related												
Current Work ability with regard to best ever	1.74	0.68	4.40	0.246								
Direct from basic military training (within 3 mo.)	1.71	0.73	4.00	0.218								
Physical training habits past 6 months												
Physical training;												
≤ 2 sessions/week	1.87	0.78	4.49	0.161	3.23	1.41	7.40	0.006	2.96	1.19	7.39	0.020
Muscular strength training;												

≤ 1 sessions/week	0.86	0.30	2.43	0.774
2-4 sessions/week	1.00			
≥ 5 sessions/week	1.82	0.79	4.22	0.161
Aerobic fitness training;				
≤ 1 sessions/week	1.41	0.63	3.15	0.408



Recruitment and measurement procedure, number of subjects included, excluded and weekly follow ups (wk.) during the marine training course. The main focus of the different phases of the course is given together with longer field exercises and leave periods. [a]One subject excluded from analysis based on LBP incidence, due to LBP at baseline that lasted for more than additional five course weeks. [b]DLL&L; Double Leg Lift & Lower test. [c]DLL&ALE; Double Leg Lift & Alternate Leg Extension.

77x28mm (600 x 600 DPI)

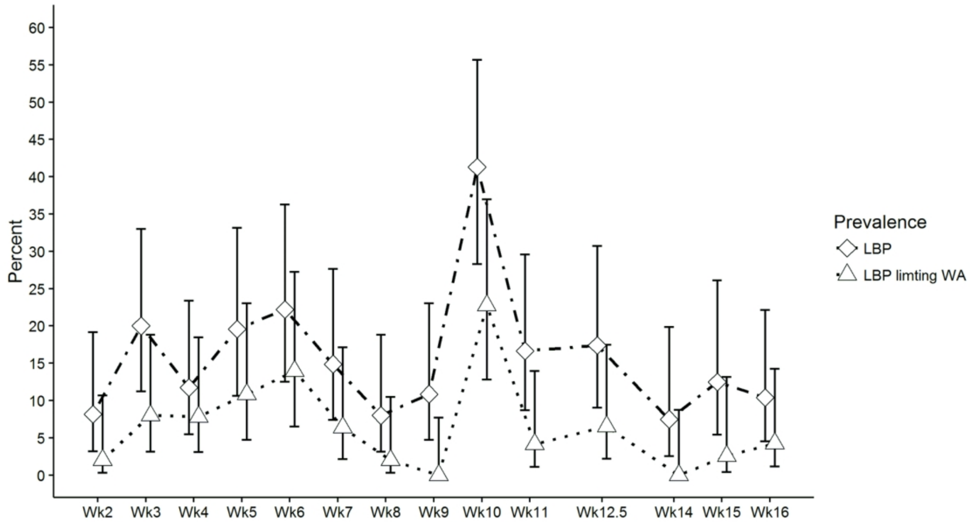


Figure 2. Weekly (Wk.) prevalence of LBP and LBP limiting work ability during the marine training course, reported as weekly proportion (percent) of cohort under study. Error bars indicate 95% confidence interval.

79x44mm (600 x 600 DPI)

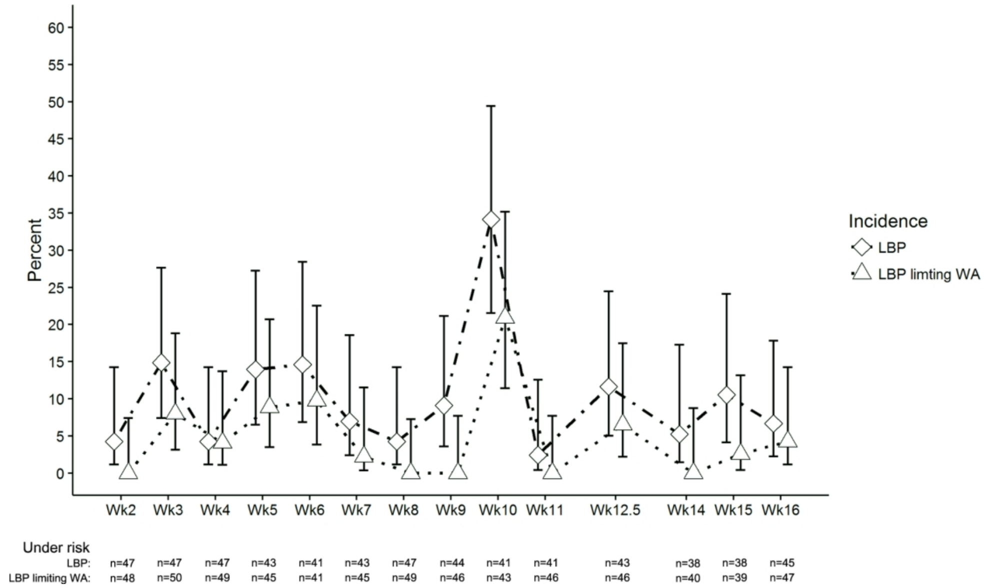


Figure 3. Weekly (Wk.) incidence of LBP and LBP limiting work ability during the marine training course. Incidence reported as weekly percent of new pain episodes of marines at risk, with 95% confidence interval (error bars) and marines at risk for new event of LBP/LBP limiting work ability.

84x49mm (600 x 600 DPI)

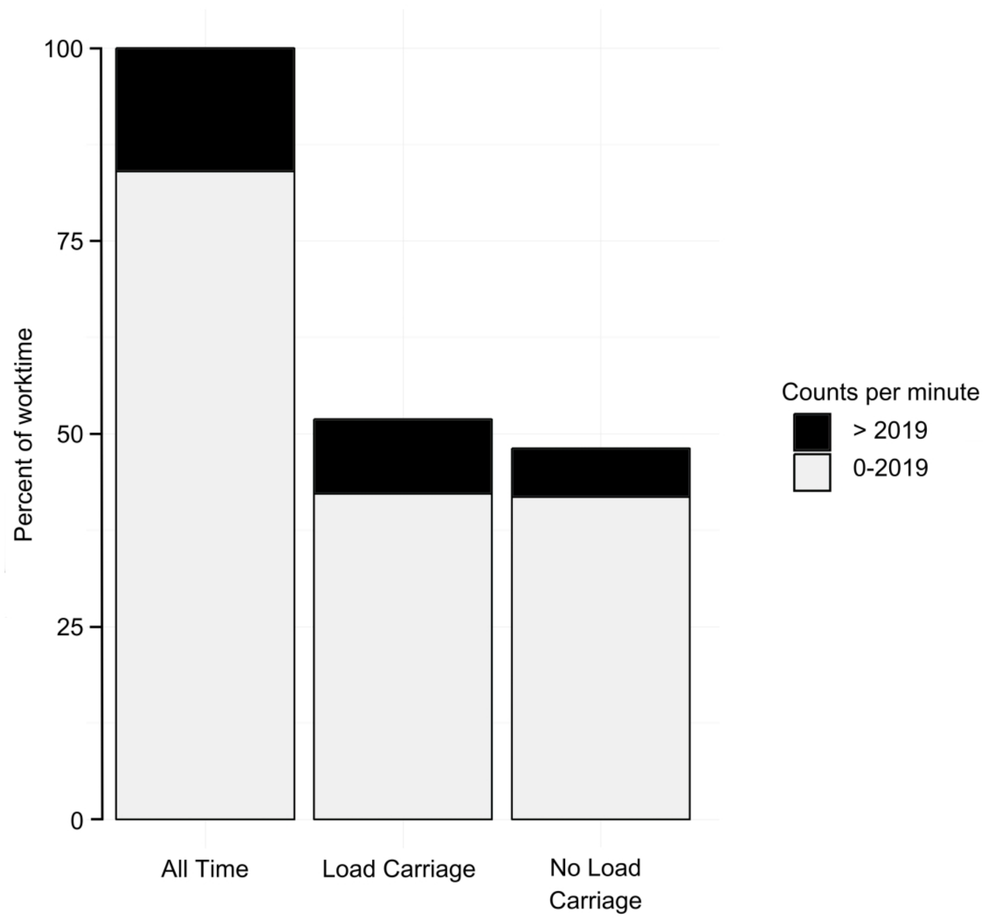


Figure 4. Proportions of work time spent in occupational physical activity generating more and less than 2020 counts per minute; in total, with, and without combat load carriage (≥17.5 kg). Work time is based on an average weekly work-time of 38 hrs (not including long distance march training, combat obstacle course or aquatic training, constituting a weekly average of an additional 2 hrs).

110x109mm (600 x 600 DPI)

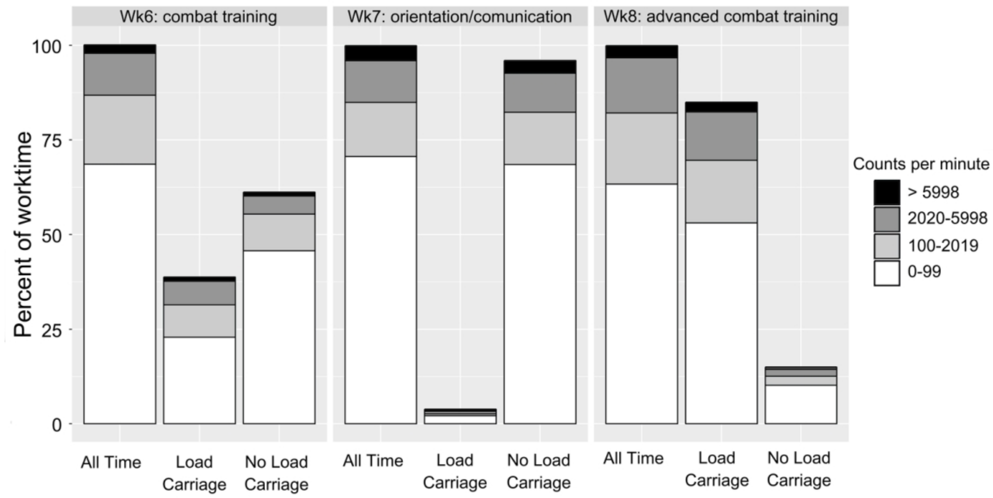


Figure 5. Proportions of work time in occupational physical activity reported per category of physical intensity (42), for total work time and time with/without combat load carriage (≥17.5Kg) for three consecutive course weeks with different learning objectives; "combat training (course week 6)", "orientation and communication (course week 7)" and "advanced combat training (course week 8)".

65x33mm (600 x 600 DPI)

Low back pain in the marine training course: A study of incidence, risk factors, and occupational physical activity

Supplementary Files

Supplementary Table 1. Incidence rate (IR) based on time to first LBP, and LBP limiting work-ability, episode during the marine training course.

	LBP			LBP limiting work ability		
	Time at risk	**IR**	**95%CI**	**Time at risk**	**IR**	**95%CI**
Per 100 person-weeks	398 person weeks	9.0	6.5-12.5	539 person weeks	3.9	2.5-6.0
Per 1000 person-days	2786 person days	12.9	9.3-17.9	3773 person days	5.6	3.6-8.5

Supplementary Table 2. Regression analyses of clinical tests: univariate and multiple final adjusted† hazard ratio (HR) for low back pain during the marine training course.

	Univariate				Final Adjusted Model[a]			
	HR	**95% CI**		**P value**	**HR**	**95% CI**		**P value**
Physical/clinical tests								
Kettlebell lifts; kg*rep								
≤760 (lowest tertile)	1.48	0.82	2.67	0.198				
Sensitivity analysis								
CC (i.e. only male)	*1.44*	*0.76*	*2.7*	*0.261*				
Imputed (only male)	*1.48*	*0.75*	*2.91*	*0.256*				
Pull-ups								
≤ 3	1.99	1.11	3.56	0.020	1.87	1.17	3.01	0.009
Sensitivity analysis								
CC (i.e. only male)	*2.00*	*1.10*	*3.66*	*0.025*	*1.82*	*1.16*	*2.88*	*0.009*
Imputed (only male)	*1.94*	*1.06*	*3.54*	*0.032*	*1.81*	*1.13*	*2.91*	*0.014*
MCM-Tests, direction specific;								
DLL-L Flex; *Fail*	0.82	0.39	1.75	0.613				
DLL-L Ext; *Fail*	0.82	0.47	1.46	0.508				
DLL-ALE Flex; *Fail*	0.71	0.32	1.56	0.388				
DLL-ALE Ext; *Fail*	1.35	0.76	2.40	0.310				

[a]Adjusted for prior back pain and body height
Abbreviations; CC; complete cases, DLL-L Flex; Double leg lift-lower lumbar flexion-control, DLL-L Ext; Double leg lift-lower lumbar extension-control, DLL-ALE Flex; Double leg lift-alternate leg extension lumbar flexion-control, DLL-L Ext; Double leg lift-alternate leg extension lumbar extension-control.

Supplementary Table 3. Regression analyses of clinical tests: univariate hazard ratio (HR) for low back pain limiting work ability during the marine training course.

	HR	95% CI		P value
Physical/clinical tests				
Kettlebell lifts; kg*rep				
≤*760* (lowest tertile)	1.02	0.67	1.54	0.923
Sensitivity analysis				
Complete cases (i.e. only male)	*1.10*	*0.31*	*3.92*	*0.884*
Imputed (only male)	*1.12*	*0.37*	*3.39*	*0.834*
Pull-ups				
≤ *3*	1.02	0.75	1.38	0.912
Sensitivity analysis				
Complete cases (i.e. only male)	*1.23*	*0.42*	*3.64*	*0.709*
Imputed (only male)	*1.29*	*0.46*	*3.60*	*0.631*
MCM-Tests, direction specific;				
DLL-L Flex; *Fail*	0.71	0.21	2.43	0.587
DLL-L Ext; *Fail*	0.85	0.35	2.06	0.715
DLL-ALE Flex; *Fail*	0.76	0.23	2.54	0.650
DLL-ALE Ext; *Fail*	0.71	0.29	1.73	0.452

Abbreviations; DLL-L Flex; Double leg lift-lower lumbar flexion-control, DLL-L Ext; Double leg lift-lower lumbar extension-control, DLL-ALE Flex; Double leg lift-alternate leg extension lumbar flexion-control, DLL-L Ext; Double leg lift-alternate leg extension lumbar extension-control.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page 3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 5
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 5
Methods			
Study design	4	Present key elements of study design early in the paper	Page 6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 6 and Fig.1
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Page 6 and 8
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Pages 8-9 and Table 1-2
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Table 1-2
Bias	9	Describe any efforts to address potential sources of bias	Page 9
Study size	10	Explain how the study size was arrived at	Page 6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Table 1-2
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 9 and 10
		(*b*) Describe any methods used to examine subgroups and interactions	Page 10
		(*c*) Explain how missing data were addressed	Page 9
		(*d*) If applicable, explain how loss to follow-up was addressed	Pages 8,9 and Fig.1
		(*e*) Describe any sensitivity analyses	Page 9
Results			Page 9

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Page 6, Fig 1. and Fig.3
		(b) Give reasons for non-participation at each stage	Page 6, Fig 1. and Fig.3
		(c) Consider use of a flow diagram	Fig 1.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 6 and table 3
		(b) Indicate number of participants with missing data for each variable of interest	Page 9
		(c) Summarise follow-up time (eg, average and total amount)	Supplementary Table 3.
Outcome data	15*	Report numbers of outcome events or summary measures over time	Page 11, Fig. 2-3 and Supplementary Table 3.
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 11, Table 4-5 and Supplementary Table 4.
		(*b*) Report category boundaries when continuous variables were categorized	Tables 1 and 2
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Page 11, Table 3-4 and Supplementary Table 4.
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 12
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Pages 12-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Low back pain in the marine training course: A longitudinal observational study of back pain incidence, risk factors, and occupational physical activity in Swedish marine trainees

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Low back pain in the marine training course: A longitudinal observational study of back pain incidence, risk factors, and occupational physical activity in Swedish marine trainees

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Abstract

Objectives: To evaluate the occurrence of LBP and LBP that limits work ability, to identify their potential early risks and to quantify occupational physical activity in Swedish Armed Forces (SwAF) marines during their basic four-month marine training course.

Design: Prospective observational cohort study with weekly follow-ups.

Participants: Fifty-three SwAF marines entering the training course.

Outcomes: Incident of LBP and its related effect on work-ability, and associated early risks. Occupational physical activity, as monitored using accelerometers and self-reports.

Results: During the training course, 68% of the marines experienced at least one episode of LBP. This yielded a LBP and LBP limiting work ability incidence rate of 13.5 (95% CI 10.4-17.8) and 6.3 (95% CI 4.2-10.0) episodes per 1000 person-days, respectively. Previous back pain and shorter body height (≤1.80m) emerged as independent risks for LBP (HR 2.5, 95% CI 1.4–4.3; HR 2.0, 95% CI 1.2–3.3, respectively), as well as for LBP that limited work ability (HR 3.6, 95% CI 1.4–8.9; 4.5, 95% CI 2.0–10.0, respectively). Furthermore, managing fewer than four pull-ups emerged as a risk for LBP (HR 1.9, 95% CI 1.2–3.0), while physical training of fewer than three sessions per week emerged as a risk for LBP that limited work ability (HR 3.0, 95% CI 1.2–7.4). More than 80% of the work time measured was spent performing low levels of ambulation, however, combat equipment (≥17.5 Kg) was carried for more than half of the work time.

Conclusions: Incidents of LBP are common in SwAF marines' early careers. The link between LBP and previous pain as well as low levels of exercise highlights the need for preventive actions early on in a marine's career. The role of body height on LBP needs further investigation, including its relationship with body-worn equipment, before it can effectively contribute to LBP prevention.

Strengths and limitations of this study

- The present unique prospective study design with weekly follow ups that is conducted early on in the marines' careers is believed to have a strong potential to fill knowledge gaps in LBP epidemiology in marine regiments and similar military units.

- The use of a repeated time-to-event regression method, with discontinued risk intervals, better reflects the recurrent nature of LBP, and makes more use of collected data than methods using single time-to-first events as an outcome.

- The definition of a new episode of LBP used in the present study does not distinguish between a new "uniquely" first event and a "symptom flare up" from a recurrent chain of events, which is a problem seen in most studies on back pain or other musculoskeletal pain problems.

- The results for the two physical "max" tests of pull-ups and kettle-bell lifts are limited to male marines only, as no female marines performed these tests.

Keywords: Back pain, longitudinal, military, musculoskeletal disorders, musculoskeletal injury, occupational exposure, physical test, prevention, work ability, work exposure.

Background

Low back pain (LBP) is an epidemiological and clinical problem; it is the leading cause of disability worldwide (1). Its nature is commonly recurrent and causes reduction in physical activity (2) and work ability (3). Societal groups associated with high levels of physical activity are indeed not spared musculoskeletal problems, and this includes highly trained military units. In fact, approximately 40% of Swedish Armed Forces (SwAF) marines on active duty experience LBP within a six-month period, and about half of these experience related limitations in work ability (4). This indicates that LBP could have a severe impact on the SwAF marines' operational readiness, as is seen internationally in marine units (5), which warrants preventive actions. Given the recurrent nature of LBP (6), preventive measures are a high priority and are believed to be most effective early in a marine's career. While the occurrence of and risk factors for musculoskeletal disorders in initial basic military training have been investigated (7, 8), the subsequent early phases of a marine's career have received less scientific attention; thus the need exists to address this gap in knowledge regarding risks for LBP in active-duty marines.

A high occurrence of musculoskeletal disorders is considered to be present by the SwAF occupational health personnel even during the four-month SwAF marine training course, where soldiers that have completed basic training are given their first marine-specific training. This physically demanding course focuses on marine-specific occupational tasks, including long range foot patrols with heavy equipment and assault operations from combat crafts (high-speed boats). Given the nature of this first and mandatory part of a marine's career, preventive measures at this stage could have a significant effect on the occurrence of future LBP in this group, and this has long been named a priority research topic in many military nations. Results gained from prospective studies in such communities, where occupational load and tasks are homogeneous and well known, have – we believe – great potential to fill knowledge gaps for further actions in defined military units.

Notably, medical examinations, health appraisals, and the evaluation of physical performance are basic routine procedures at the start of a military training course or before deployments. Information from such early examinations along with known risks from civilian contexts, such as a history of previous pain episodes (9, 10), physiological distress, or lifestyle factors (10, 11), has the potential to provide relevant risk information in operating activities. While low physical capacity and low performance on military physical fitness tests have previously been indicated as risks for LBP (12, 13), the screening of marines or similar elite units before entering the course with valid tests for their occupational exposures is not presently performed. New physical screening protocols have indeed been developed and introduced for other SwAF units, covering areas possibly related to the development of LBP in marines as well, for example lifting- and load-carrying capacities (14).

In addition, objective monitoring of occupational physical activity during the marine training course will aid in the interpretation of identified risks – such objective data has also been warranted for a long time. This study therefore aimed to prospectively evaluate the occurrence of LBP and its effect on work ability, as well as to identify potential early risks for such disorders in soldiers during the marine training course. Further aims were to quantify occupational physical activity and work-related exposure during the course.

Methods

Study design

This study used a prospective observational design with a cohort of SwAF marines entering the four-month marine training course. A screening program consisting of a self-administered questionnaire and a battery of physical tests was conducted at the start of the course, while pain occurrences were then followed up on a weekly basis. Occupational physical activity was continuously monitored with accelerometers worn during working hours for seven weeks of the course by a sub-cohort of participants; this was supplemented by platoon and individual logs of work tasks and physical training. All data collection was conducted at the 1st Marine Regiment, Stockholm, Sweden, between January and May, 2015. The study was approved in advance by the Regional Medical Research Ethics Committee, Stockholm (2014/1904-31/2). After receiving written and oral information on the study, signed informed consent was obtained from all participants prior to enrolment. Measurement occasions and the focus of the different phases of the course are illustrated in Figure 1, along with information on the participants' progression throughout the study.

Figure 1. about here

Patient involvement

Given the defined target group in the present study, no patients seeking medical care were recruited. The present research questions and outcomes are based on data/conclusions from our on-going translational research on active duty marines (4, 15); it is also influenced by our empirical knowledge and clinical work in this population. The Marines' medical and occupational health services have taken part in planning the data collection, and they constitute the primary way of implementing the results in clinical work for the studied population.

Participants

To be eligible for inclusion in the present study, marines had to have the intention to complete the entire marine training course. Of 56 eligible marines, 53 met the criterion, and were enrolled in the study. The mean (SD) age, body weight, height, and body mass index for the enrolled marines were: 21.8 (3.4) years, 80.0 (10.1) kg, 1.82 (0.07) m and 24.1 (2.5) kg/m^2, respectively. The majority of participants (91%, n=48) were men. Ten (19%) had experienced pain in the lower back within six months prior to baseline. Marines with on-going LBP at baseline lasting for five or more consecutive weeks adjacent to the course start (n=1) were excluded from analysis based on incidences.

Measurements and Procedure

Baseline questionnaires

Participants initially completed confidential questionnaires to elicit military and demographic background information (4), general health (16) and mental health (17), self-assessed work ability (16), and physical training habits. The questions, which are described in detail in Table 1, have previously been used in international and Swedish public health cohorts and studies of active duty SwAF marines. The questionnaires also included detailed information on musculoskeletal pain for nine anatomical areas (18) within the past week and six months, with the following reporting options: For pain within the past week *"No pain"* or *"Pain"* and for pain within the past six months *"No pain"*, *"Pain a couple a days per month or less",* or *"Pain a couple of days per week or more".* Pain limiting work ability was assessed using the options *"Not limited"*, *"Limited to some extent",* or *"Limited to a large extent"*.

Table 1 about here

Physical baseline tests

Physical tests focusing on muscle strength and movement control were performed during the first ten days of the course. These tests, described in detail in Table 2, were selected on the basis of their use in clinical/preventive work among the studied population or in screening programs within the SwAF, and have previously been found reliable for use with active duty SwAF marines(23) or similar SwAF units (14). The strength tests, which were conducted following standardised SwAF instructions (14), were:

- *Kettlebell lifts* - The number of (correct) lifts of a pair of kettlebells (2 x 16, 24, or 32 kg) completed in a one-minute interval (14) and,
- *Pull-ups* - The number of (correct) pull-ups completed, performed hanging from a bar with an overhand (pronated) grip (14).

These tests were conducted within a series that also including a loaded lower limb functional test (24) (performed before these tests) and the ranger (loaded) step test (25) (performed after these tests), which are described in detail elsewhere (24, 25).

The two movement control tests were derived from the descriptions by Comerford and Mottram (26) and tested for good reliability in SwAF marines (23). These tests focus on the ability to actively control or prevent compensatory movement in the lumbar spine, i.e. flexion, extension or rotation, while actively moving the lower extremities. The tests, conducted following standardised instructions, (23) were:

- *Double Leg Lift & Lower (DLL&L):* The subject, from a supine position, lifts both feet off the bench to a 90° hip flexion, and then lowers them back to the bench. Any uncontrolled movements in flexion or extension were recorded in the test protocol.

- *Double Leg Lift & Alternate Leg Extension (DLL&ALE):* The subject, from a supine position, lifts both feet off the bench to a 90° hip flexion, then lowers and straightens one leg to a fully extended position and then back to a 90° hip flexion. The procedure was then repeated with the other leg, after which both legs were lowered to the starting position. The direction of any uncontrolled movements in extension, flexion, or rotation was recorded in the test protocol.

Table 2. about here

Continuous assessment of work-related physical activity and occupational tasks

Twenty-seven marines from the inception cohort were randomly assigned by a computer-generated algorithm to wear accelerometers during the course. Six declined, leaving 21 marines in this sub-cohort. They were fitted with tri-axial accelerometers (GT3X+BT, Actigraph, Pensacola, FL) and instructed to wear them on the left hip during all working hours of the course, with the exception of planned prolonged loaded marches (due to the risk of interaction with back pack hip belts resulting in abrasions or compression injuries), aquatic physical training, or during training conducted at the marine combat obstacle course (due to water obstacles). They were also instructed to remove them during field exercises conducted at other bases during weeks 11-13 of the course due to an inability to collect data at these locations. The accelerometers were initialised using ActiLife software (version 5.5), with data sampling set at a rate of 30Hz. Information on occupational tasks and equipment worn, and physical training sessions conducted, was recovered from detailed weekly schedules completed by the instructing officers, as well as from the self-reported diaries kept by the marines.

Weekly follow-up

Incidence of musculoskeletal disorders and related effect on work ability were self-reported weekly during the course, using a short version of the baseline questionnaire. The number of responders for each week is illustrated in Figure 1. Weekly follow-ups were not strictly possible due to the geographic location of training during course week 12, so the follow up was conducted at the beginning of week 13 and reported as week 12.5 (i.e. week 12 and half of week 13).

Outcomes

LBP was defined as the occurrence of any self-rated pain in the lower back (from the twelfth ribs to the lower gluteal folds (27) within the preceding week, as reported during the weekly follow-up. LBP limiting work ability was defined as the occurrence of any self-rated pain in the lower back within the preceding week that had limited work ability.

For incidence proportions, rates, and regression analysis (described in detail below), marines were considered to be at risk for an event as long as they were under observation, and until the occurrence of a LBP event. At the time of pain occurrence, the risk interval was discontinued and marines were not considered to be at risk for a new episode until they were pain free for the next coming week (if reporting no pain in that week, it was counted, if reporting pain also that week, the week remained censored). Meeting this requirement automatically allowed them to re-enter the analysis (pain observation period). Marines with on-going LBP at baseline were not considered at risk until they were pain free for at least one week, at which point in time they entered the analysis. Late entry was only allowed during the first four weeks to accurately reflect the independent variables collected at baseline.

Independent variables

Independent variables analysed as potential risk factors for LBP and LBP limiting work ability were selected based on existing evidence from active-duty SwAF marines, other military and civilian populations, and empirical knowledge from clinical work with the SwAF marines. These 17 variables, including two physical characteristics, four health-related, two work-related, three on physical training habits, and the results of the two strength and the two movement control tests (in flexion and extension), are described in detail in Table 1 and 2.

Confounding variables

Age, *BMI*, *sex*, *smoking*, *non-musculoskeletal co-morbidity,* and *LBP previously during the course* were a priori considered possible confounders. A confounder was defined as a variable that, when included during the analytic process, changed the hazard ratio of the crude regression model >20% (28).

Data management and statistics

Missing data

The dependent variables, i.e. LBP and LBP limiting work ability, were missing for 11% of the data due to subjects' lost to follow-up during the course. Also, of the independent variables, the kettlebell lift tests were missing for 30%, the pull-ups 23%, and the DLL-ALE test 4%, due to participants not being able (or allowed) to perform the test at baseline (illness such as having a cold or other infection in 44% of these and pain or similar co-morbidity in 56%). All female marines (n=5) missed the kettlebells lift and the pull-ups tests due to illness or on-going pain. Based on the analysis of the missing data mechanism (29), however, the data for outcomes and the DLL-ALE test were considered to be "missing completely at random" (i.e. the reason for data to be missing was not dependent of the missing data itself nor predicted by the independent variables included the analysis) and missing data on the kettlebell lift and the pull-ups tests to be "covariate missing completely at random" (missing data predicted by bodyweight and body height). Multiple imputations by Markov chain Monte Carlo, with random draws based on Jeffreys prior distribution, were used to generate 50 imputed datasets with completed data on all predictor variables, on which the pooled analyses were based (30). Given that no female marines performed the two strength tests, imputing values for females based on data from only male marines on these tests might affect the accuracy of the imputation. Therefore, regressions including these two tests were repeated, as part of the sensitivity analysis, on only complete cases, as well as on multiple imputed data with females excluded.

Descriptive statistics

LBP and LBP limiting work-ability

Weekly prevalence was analysed as a percentage of those under observation, with 95% CI (31). Weekly incidence of LBP and LBP limiting work ability was analysed as a percentage of those at risk, with a 95% CI (31). The incidence rate of LBP and LBP limiting work ability during the course was calculated based on the number of episodes and the time at risk, presented as episodes per 1000 person-days, with a corresponding 95% CI (32).

Work-related physical activity and occupational tasks

Accelerometer data were analysed only if sufficient wear time could be established, which was defined as at least 180 minutes of wear time per day (for full work days) on at least three workdays (for a five-day week). Non-wear time within days was identified by algorithms suggested by Choi (33). For valid wear-time, vertical counts per minute (cpm; where the arbitrary unit of counts is the filtered raw acceleration generated by body movements and captured by the accelerometer) - based on 10-second epochs - were extracted and reported as minutes and percentage of total work time, and work time per week spent in these predefined categories: 0-99; 100-2019; 2020-5998; and 5999- cpm (34). Here, the category of 2020-5998 cpm was considered to be comparable to slow to brisk walking (~3.8-7.5 km/h) (35, 36). In addition, the percentage of the workday spent in these categories was reported for time with and without load carriage (combat equipment, ≥17.5 Kg), as identified from the detailed schedules (verified against activity logs). Evaluation and comparison with work schedules were performed visually.

Regression analysis

We used the Andersen-Gill repeated time-to-event regression method (37, 38) with the robust sandwich variance estimator (39), and discontinuous risk intervals (38), as defined above, to examine the predictive association between the independent variables and LBP. The results are reported as hazard ratios (HR) with a corresponding 95% CI. Secondly, this method was applied to examine the predictive association between independent variables and LBP limiting work ability.

Independent variables were analysed in two blocks. First, *physical characteristics, work- and health-related* variables, as identified with univariate time-to-event regressions to be associated with the dependent variable, at the level of $p<0.20$, were included in a multivariable time-to-event regression model. This was followed by an iterative, purposeful selection process of deleting non-significant variables at p>0.05. The model was then refitted and verified until a final model contained only significant (p<0.05) independent variables, identified confounders, and significant (p<0.05) interactions (between independent variables in the final model and/or independent variables and confounders) (28). This process was repeated for the *clinical tests*, with the addition of the significant *physical characteristics, work- and health-related* risk factors addressed as additional potential confounders. Due to the relatively small sample size, the confidence interval for borderline significant independent variables were inspected for incorrect omission from final models (40). All final models were deemed to have sufficient confidence interval coverage, based on the events-per-variable ratio (40). Using methods described by Cleves et al. (41), final models showed no violations of underlying assumptions of proportional hazards (e.g. tests based on reestimation, interaction of analysis time with the independent variables and graphically through Schoenfeld residuals) and showed appropriate model fit. Analysis was performed using STATA Statistical software (version 13.1; College Station, TX).

Results

Table 3 presents demographic and background data as well as self-rated general health for the 53 marines who completed the baseline questionnaire (96% response rate). Good or excellent current health status was reported by >95% of respondents. Of the 53 marines starting the course, 49% joined directly from basic military training, while the other 51% came from previous service in the SwAF or from a period of civilian occupation/studies.

LBP and LBP limiting work-ability

Figures 2 and 3 present the prevalence and incidence of LBP and LBP limiting work ability, expressed per week during the marine training course. A total of 68% of the marines experienced at least one episode of LBP during the course, of whom 57% reported related limitations in their ability to work. The average LBP episode consisted of 1.6 weeks of reported pain, with 42% of the sufferers experiencing at least one recurrent episode (with an average of 2.8 weeks without reporting pain between episodes). This gave an LBP incidence rate of 13.5 (95% CI 10.4 to 17.8) episodes per 1000 person-days. For LBP limiting work ability the corresponding incidence rate was 6.3 (95% CI 4.2 to 10.0). For comparison, incidence rates based on time to first event (during the course) are presented in supplementary Table 1.

Fig. 2 and 3 about here.

Risk factors for LBP and LBP limiting work ability

Individual physical characteristics, work- and health-related risk factors

Tables 4 and 5 present the results from univariate, final unadjusted and final adjusted multivariable recurrent-event regression models for LBP and LBP limiting work ability during the course. *Back pain (lumbar* and/or *thoracic back pain)* within six months prior to the MTC and *shorter body height (≤1.80m),* adjusted for the confounding effect of *sex* (LBP and LBP limiting work ability) and *previous neck shoulder pain* (LBP limiting work ability), were identified as independent risks. Additionally, *less than three sessions per week of physical training* was a significant risk for LBP that limited work ability. No interactions between the independent variables, nor with the confounders, emerged as significant in any of the models. Inspecting the 95% CI of excluded variables did not indicate any non-correct exclusion of potential risk factors. For comparison, initial multiple models for LBP and LBP limiting work ability are presented with 95% CI in supplementary Table 2.

Tables 4 and 5 about here.

Clinical tests

Performing fewer than four pull-ups (HR 1.9, 95% CI 1.2–3.0), adjusted for confounding effect of *previous BP* and *body height*, was identified as a significant risk for LBP. However, no clinical tests were associated with LBP limiting work ability at $p<0.05$. Final unadjusted and adjusted models for LBP limiting work ability are presented in Supplementary Tables 3 and 4. Sensitivity analysis based on complete cases and imputed data, with only males, caused only marginal changes in the results, with no effect on inference.

Work-related physical activity and occupational tasks

Of the seven weeks of measurement, five contained sufficient wear time that could be fully used for analyses. During these weeks, an average of 16% of the working time (73 minutes per day) (not including long-distance march training, combat obstacle course or aquatic training, with a weekly average of additionally 2 hrs), was spent in physical activity of at least moderate intensity, i.e. 2020-5998 cpm, or slow-to-brisk walking (~3.8-7.5 km/h). On average, four percent of total working time was spent in physical activity of at least vigorous intensity, i.e. >5998 cpm. Sixty-one percent (44 min. per day) of the time spent in activities generating >2020 cpm was conducted wearing combat equipment (≥17.5 kg), as illustrated in Figure 4. There was, however, a large variation across weeks in work-time wearing combat equipment that spanned from 4% to 94%, as exemplified in Figure 5.

Discussion

This prospective cohort study among Swedish marines showed a high occurrence of LBP and consequent limitations in work ability while participating in their basic training marine-course. Marines with a history of previous back pain, shorter body height, or poor performance in the pull-up test were twice as likely to experience a new episode of LBP during this four-month period of physically demanding marine tasks.

This study followed 95% (n=53) of the participants enrolled in a typical marine training course in the Swedish Armed Forces (SwAF). Our cohort was homogeneous with regard to demographic characteristics and occupational tasks, which is similar to previous studies of marines (4), and may be regarded as a representative military-marine sample. While the sample size constituted the majority of the eligible Swedish marine trainees, caution has been taken to avoid over-fitting of statistical models. The effect of the relative small sample size on precisions of the estimate was here reflected in the somewhat wide confidence intervals. Furthermore, given the heightened risk of non-identification of a true risk factor, omission of borderline significant risks, i.e. not reaching significance in the present study, should not exclude them for further investigation in other similar cohorts in the military community. The loss of power could have been avoided by including data from future training courses (i.e. accumulating a larger sample), other military courses, or by prolonging the follow up period (i.e. including time after the course) (42). For the present study's aims, however, we believe it was more important to emphasize sample homogeneity and specific work-related exposure, as we believe this to be one of the most challenging factors to control for in studies of military populations.

We believe this study to be the first to use a repeated time-to-event regression method, with discontinued risk intervals, for LBP in a military population. This method may – we believe – better reflect the recurrent nature of LBP and make more use of the collected data than the conversional methods using time-to-first event. The definitions of a new event vary between studies (43), but a pain-free period of one week was considered sufficient for an additional event to be defined as either a new event or symptom "flare up" (44) from a previous event. Given that this definition does not distinguish between a new "uniquely" first event or symptom "flare up" from a recurrent chain of events, potential differences in the mechanism for new and recurrent pain could not be further disentangled in this study. Regarding our baseline testing, marines that were injured (n=9) or ill (n=7) were not allowed to perform the "max effort" tests, because of the risk of worsening their health. However, analysis based on complete cases, as well as on imputations including only males, did not change the results, indicating an appropriate inference from the present results. Due to none of the female marines conducting the two "max" tests of pull-ups or kettle-bell lifts, these results should only be extended to males.

Our results show a relatively high incidence of LBP in this cohort of young marines, with more than two thirds experiencing at least one LBP episode during the course. This is almost twice the reported six-month LBP prevalence for active duty SwAF marines (4), more than twice the LBP incidence in the British combat infantryman's course (45), and higher than the total musculoskeletal injury incidence in other military training cohorts (46-48). This difference in pain occurrence may partly be explained by differences in the length of follow-up periods (49), or how LBP was defined (50). However, the recall period in this study was relatively short, and as such should limit the risk of recall bias. Given that three of five marines experiencing LBP also reported related limitations in work ability, it is likely that LBP reduced the intended goals with the course, and this may have future negative effects on the operational readiness of SwAF marine units.

Although previous musculoskeletal disorders are considered to be the strongest predictor for new musculoskeletal disorders in military populations (15, 47, 51, 52), it is not clear if such previous pain-episodes are anatomically region-specific in their prediction. This might not make a substantial difference in general primary prevention policy decisions, but the present findings could – we believe – help clinicians to be more specific in their selection of suitable secondary preventive measures for LBP. However, until the pathophysiological pathways between prior and future pain episodes are further disentangled, this does not inform the clinician what specific deficiencies to address. As such, the current use is limited to identifying persons at risk of LBP (53); marines at risk should be considered for further clinical examination and secondary preventive action. The same goes for marines with a body height of ≤1.80m, here identified as a risk for both LBP and LBP limiting work ability. While risks associated with body height are in line with our previous results (4), it is not likely that a short body height per se constitutes the actual risk, it could potentially represent an interaction with equipment worn or specific work tasks conducted.

The present results also highlight the need for regular physical training (≥ 3 sessions/week) for military personnel planning to attend the marine training course. This is in line with recommendations for general health in the civilian population (54), and should certainly be stressed for this physically active military community as well. Here, inferior upper-body strength, as tested by the pull-up test, seems to have played a role in back pain aetiology. This test, used in different forms in many military physical assessments (14, 55), is considered a relevant test of the ability to navigate over obstacles (14), but also as a proxy for general upper-body strength and muscle endurance (56). The test primarily challenges the back, shoulder and arm muscles, but also to a moderate extent the external oblique and erector spinae muscles (57). As such, it could represent a valid test for marines as upper body strength is crucial for load carriage (58). No female marines conducted these tests, therefore future cut-offs need to be validated for them. Neither the kettlebell lifts nor any of the movement-control tests predicted future LBP, however, "core-strengthening exercises" were already conducted as part of the marines' daily calisthenics in this sample, potentially preventing such deficits early in the course. Still, the results tally with our previously reported results from active duty marines, where these tests, analysed as overall pass/fail, failed to predict back pain within a six- and 12-month event window (15). While the present study aimed at identifying early risks for LBP, the sample size limited the exploration of potential effect measures modification in the final models to two-way statistical interactions. These analyses did, however, not provide any evidence of previous back pain affecting the amount of physical training and upper body strength in relation to a new back pain episode. The direction of temporality could however only be addressed for the six months preceding the course start. Still, physical training is recommended as primary (59-64), secondary (59, 60, 62, 64), and tertiary (59-64) preventive actions for back pain in both general populations and occupational settings. This highlights the potential role of physical training as a preventive action against future back pain episodes for marines displaying these identified risks.

While the physical demands of the course could be one reason for high LBP incidence, more than eighty percent of the work time measured was spent at low levels of ambulation, i.e. producing less than 2020 cpm. These results were similar to, or lower than, ambulatory movements reported for basic military training courses (65-67). However, in comparison with the US basic military training, where loads of no more than 4.5 kg were carried for 80% of the time (65), the marines in the present study carried combat equipment weighing >17.5 kg for more than half of the measured work time. In addition, the maximum weight of equipment worn on certain occasions, such as during loaded marches, can at times be more than twice that. Considering that both body-worn equipment and load carriage has been linked to LBP in deployed military personnel (12), this may possibly relate to the high LBP incidence in the present study. Furthermore, it highlights the need to consider load carriage when examining the association between ambulatory movement and LBP in the military context.

In summary, LBP and related limitations in work ability are common during the four-month physically demanding marine training course, and may affect the future operational readiness of marine units. Since previous LBP episodes are the most consistent risk for further LBP, marines entering the course with a history of LBP should receive tailor-made secondary preventive actions. Furthermore, marines with few weekly sessions of physical training, or with insufficient upper body strength, should be considered for targeted physical training. Further investigation on the role of body height on LBP is needed, including its relation to body-worn equipment, before it can be effectively used in LBP prevention. In addition, while ambulation was low for parts of the course, combat equipment was carried for more than half of the work time, further indicating the need to consider the role of body-worn equipment in LBP aetiology for this population.

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Contributorship statement

AM was the main writer of the paper and participated in the conception and design of the study, and acquired, analysed and interpreted the data. HL and HN participated in the conception and design of the study, planning of the analysis, interpretation of the data as well as the writing and revising of the paper. MD was involved in the design and planning of the study, as well as interpreting the data and revising the paper. As senior project researcher, BOÄ participated in the conception and design of the study, planning the analysis and interpretation of the data, and writing and revising the paper. All the authors have read and approved the final manuscript.

Competing interests

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Data sharing statement

No additional data are available.

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Tables

Table 1. Self-reported independent variables, the form in which they were included in regression analysis, procedures for retrieving the data and rationale for categorisation.

Independent variable	Reference	Exposure	Measurement procedure and variable management
Physical characteristics			
Body weight	Continuous		Body weight (in Kg) was self-reported and analysed as a continuous variable in the models.
Body Height	> 1.80m	≤1.80m	Body height was self-reported. Based on the hypothesis that being either "too tall or too short" may be negative for musculoskeletal health in this environment, as previously identified for this population (4), *body height* was initially categorised as ≤1.80m, 1.81-1.85m *(reference)* and ≥1.86m (representing body height tertiles of the SwAF marine population, (4, 15), but was reduced to a dichotomised variable due to no difference between the upper and the reference category being identified.
Rated health/health history			
Back Pain; within 6 mo. prior to course start	No	Yes	Self-reported musculoskeletal pain in the lower and/or thoracic back , defined as *"Pain a couple of days per month or less"* or *"Pain a couple of days per week or more"* within the past six months, analysed dichotomised as *yes* or *no* as previously for this population (4, 15).
Hip/Knee Pain; within 6 mo. prior to course start	No	Yes	Self-reported occurrence of musculoskeletal pain in the *hip* and/or *knee*, defined as *"Pain a couple of days per month or less"* or *"Pain a couple of days per week or more"* within the past six months, analysed dichotomised as *yes* or *no,* as previously for this population.
Neck/Shoulder Pain; within 6 mo. prior to course start	No	Yes	Self-reported musculoskeletal pain in the *neck* and/or *shoulder*, defined as *"Pain a couple of days per month or less"* or *"Pain a couple of days per week or more"* within the past six months, analysed dichotomised as *yes* or *no,* as previously in this population.

Mental distress (GHQ-12 Score)	<4	≥4	The level of mental distress was captured by the General Health Questionnaire-12 (19), a widely used screening instrument developed to detect "cases" of mental distress. It is a 12-question tool, summed up to give an overall score, ranging from 0 to 12, and a cut off of 4 points or more is considered an indication of clinically relevant mental distress (20). As such, "*Mental distress*" was categorised as ≥4 on the summary GHQ-12 scale.
Work related			
Current work ability with regard to best ever	≥9	<9	Self-rated work ability captured with the single item question from the work ability index (16). Current work ability was rated, with regard to ever best, on a 10-point ordinal scale. Based on the hypothesis that "less-than-optimal" work ability could constitute a risk in this environment, the responses were dichotomised as high (≥9) (*reference*) and moderate (<9).
Direct from basic military training (within 3 mo.)	No	Yes	Finishing basic military training within three months of the course start was considered a risk, due to the assumption that these soldiers had had less time to adapt to load carriage within the military. Therefore dichotomised as *yes* or *no (reference)*.
Physical training habits			
Physical training; sessions per week	>2 sessions /week	≤2 sessions /week	Average number of training sessions per week, exceeding 20 minutes, were rated on a five point ordinal scale as ≤1 day/week, 2 days/week, 3-4 days/week and ≥5 day/week. This item was derived (in addition to an increased number of maximum sessions) from items previously used in several public health cohorts in Sweden (21, 22). A U-shaped relationship with LBP was hypothesised for number of physical training sessions per week, i.e. too little and too much training may both be risks for LBP. Consequently, the training sessions per week variable was categorised as ≤2 session/week, 3-4 sessions/week (reference) and ≥5 sessions/week, but reduced to a dichotomised variable for LBP limiting work ability as no significant difference between the upper and reference category was found.
Muscular strength training; session per week	2-4 sessions /week	≤ 1 sessions /week	A U-shaped relationship with LBP was hypothesised for number of strength training sessions per week, i.e. too little and too much training may both be risks for LBP. Consequently *Weekly strength training* was categorised as ≤1 session/week, 2-4 sessions/week *(reference)* and ≥5

		≥5 sessions /week	sessions/week.
Aerobic fitness training; sessions per week	>1 session /week	≤ 1 sessions /week	*Weekly aerobic training* was dichotomised as ≤1 session/week or >1 *(reference),* given two session per week a priori considered to be a realistic minimal amount of cardio vascular training necessary to maintain sufficient aerobic capacity during the physically demanding basic military training course.

Table 2. Physical test; independent variables, the form in which they were included in regression analysis, procedures for retrieving the data and rationale for categorisation.

Independent variable	**Reference**	**Exposure**	**Measurement procedure and variable management**
Strength tests			
Kettlebells lift; kg x repetitions	> 760	≤760	Pairs of kettlebells weighing 32, 24, or 16 kg each were used. The intended test weights were 2x32 kg, but subjects unable to perform the test safely with these loads could choose the lighter kettlebells. To make sure that the correct and safe lifting technique was used, all participants performed two test-lifts using a lower weight while being supervised by the test leader. The test measured the number of (correct) lifts of the weights performed in one minute. Based on the assumption that marines with the lowest lifting capacity are at greater risk of LBP, the lower tertile of the product of "numbers of lifts x weight lifted" was compared to the upper two tertiles (reference).
Pull-up; number of	≥ 4	≤ 3	Hanging from a pull-up bar, using an overhand grip with hands placed shoulder-width apart, the participants lifted their body until their chin was level with the bar. The number of (correct) lifts

repetitions			performed in one minute was recorded in the test protocol. The number of correct 'chins' is dichotomised as ≤3 or ≥4 *(reference).* Internationally, the cut-off for passing a pull-up test during yearly physical assessments for marines ranges from 3 (US marines) to 5 (Royal Marines) and as such, assuming that marines with the lowest pull-up capacity are at greater risk of LBP, the cut-off for the reference category was set at the median, ≥4 pull-ups (*reference*).
Movement control tests			*To make sure failure of any of the movement control tests was due to a "real" inability to control direction and not unfamiliarity with the test movement, all participants performed the test three to six times with feedback from the tester to ensure familiarisation. To monitor the movement of the lumbar spine, an air-filled pressure sensor (Pressure Biofeedback Unit, Chattanooga Group, Hixon, TN) was placed under the lower back.*
Double Leg Lift & Lower	pass	fail	The test assesses the ability to prevent extension and flexion of the lumbar spine (26). The subject, from a supine position, lifts both feet off the bench to a 90° hip flexion, and then lowers them back to the bench. Any uncontrolled movements in flexion or extension, defined as an ≥5mmHg change (from the starting pressure of 40mmHg), were recorded on the test protocol. Test performance on *flexion* and *extension* assessed in the tests was analysed as pass or fail.
Double Leg Lift & Alternate Leg Extension:	pass	fail	The test assesses the ability to prevent extension, flexion and rotation of the lumbar spine, and leg abduction, lateral rotation, and hip forward glide (26). The subject, from a supine position lifts both feet off the bench to a 90° hip flexion, then lowers and straightens one leg to a fully extended position and then back to a 90° hip flexion, before repeating the test on the other side. The direction of any uncontrolled movements, defined as ≥5mmHg change (from the starting pressure of 40mmHg), was recorded on the test protocol. Test performance for *flexion* and *extension* assessed in the tests was analysed as pass or fail.

Table 3. Demographic characteristics, physical characteristics and self-rated health at baseline.

	Mean	SD
Age (years)	21.8	3.4
Body weight (kg)	80.0	10.1
Body height (m)	1.82	0.07
Body mass index (kg/m^2)	24.1	2.5
GHQ-12 Score	1.8	1.6
Muscular strength training; hours per week[a]	4.5	2.7
Aerobic fitness training; hours per week[b]	3.1	1.9
	%	**95% CI**
Smoking		
No	71.7	58.4-82.0
Occasionally	28.3	18.0-42.6
Yes	0.0	0.0-6.8
Snus (smokeless tobacco)		
No	64.2	50.7-75.7
Occasionally	11.3	5.3-22.6
Yes	24.5	14.9-37.6
Baseline testing	**Mean**	**SD**
Pull-ups	7.8	5.2
Kettlebell lifts		
Average lifts	17.6	6.4
Kettlebell, average weight (x2)	29.8	4.1
	%	**95% CI**
MCM-Tests, per direction;		
DLL-L Flex; Fail	19.2	10.8-31.9
DLL-L Ext; Fail	34.6	23.2-48.2
DLL-ALE Flex; Fail	19.6	11.0-32.5
DLL-ALE Ext; Fail	43.1	30.1-56.7

Note: Reported with mean and standard deviation (SD) or percentage and corresponding 95% Wilson Score confidence interval (95% CI).

[a]Average weekly hours of muscular strength training during previous six months (median (interquartile range) all; 4(3.5), males; 4(3.5), females 3(3)).

[b]Average weekly hours of aerobic fitness training during previous six months (median (interquartile range) all; 3(2), males; 3(2), females 5(3)).

Table 4. Regression analyses of individual physical characteristics, work- and health-related risk variables: univariate and multiple final adjusted[†] hazard ratio (HR) for low back pain (LBP) during the marine training course.

Variable	Univariate				Final Crude Multivariable				Final Adjusted Multivariable[a]			
	HR	**95% CI**		**P value**	**HR**	**95% CI**		**P value**	**HR**	**95% CI**		**P value**
Physical characteristics												
Body weight (kg)	1.01	0.99	1.03	0.441								
Body Height ≤ 1.80 (m)	1.48	0.84	2.58	0.172	1.73	1.03	2.92	0.040	1.98	1.19	3.29	0.009
Rated health/health history												
Mental distress (GHQ-12 Score)	2.08	0.65	6.70	0.219								
Back Pain; within 6 mo. prior to course start	2.00	1.09	3.64	0.025	2.26	1.27	4.03	0.006	2.47	1.41	4.31	<0.001
Hip/Knee Pain; within 6 mo. prior to course start	1.50	0.85	2.66	0.163								
Neck/Shoulder Pain; within 6 mo. prior to course start	1.63	0.91	2.90	0.098								
Work-related												
Current Work ability with regard to best ever	1.69	0.97	2.94	0.064								
Direct from basic military training (within 3 mo.)	1.08	0.62	1.91	0.779								

Table 4. cont.	Univariate				Final Crude Multivariable				Final Adjusted Multivariable[a]			
	HR	**95% CI**		**p value**	**HR**	**95% CI**		**p value**	**HR**	**95% CI**		**p value**
Physical training habits past 6 months												
Physical training;												
≤ 2 sessions//week	1.18	0.53	2.64	0.692								
3-4 sessions/week	1.00											
≥ 5 sessions//week	1.29	0.70	2.37	0.418								
Muscular strength training;												
≤ 1 sessions/week	0.90	0.52	1.54	0.690								
2-4 sessions/week	1.00											
≥ 5 sessions/week	1.27	0.58	2.78	0.542								
Aerobic fitness training;												
≤ 1 session/week	1.24	0.66	2.36	0.502								

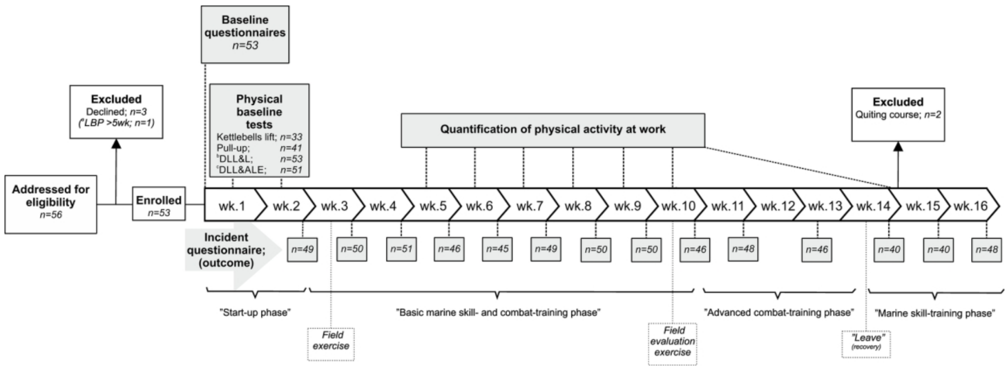
[a] Adjusted for confounding effect of sex

Table 5. Regression analyses of individual physical characteristics, work- and health-related risk variables: univariate and multiple final adjusted[†] hazard ratio (HR) for low back pain (LBP) limiting work ability during the marine training course.

Variable	Univariate				Final Crude Multivariable				Final Adjusted Multivariable[a]			
	HR	**95% CI**		**p value**	**HR**	**95% CI**		**p value**	**HR**	**95% CI**		**p value**
Physical characteristics												
Body weight (kg)	1.00	0.96	1.04	0.991								
Body Height ≤1.80 (m)	2.20	0.96	5.03	0.062	3.04	1.35	6.86	0.007	4.48	2.01	9.97	<0.001
Rated health/health history												
Back Pain; within 6 mo. prior to course start	2.48	1.04	5.91	0.040	4.47	1.80	11.11	0.001	3.58	1.44	8.90	0.006
Hip/Knee Pain; within 6 mo. prior to course start	1.15	0.41	3.23	0.784								
Neck/Shoulder Pain; within 6 mo. prior to course start	2.79	1.18	6.57	0.019								
Work-related												
Current Work ability with regard to best ever	1.74	0.68	4.40	0.246								
Direct from basic military training (within 3 mo.)	1.71	0.73	4.00	0.218								
Physical training habits past 6 months												
Physical training;												
≤ 2 sessions/week	1.87	0.78	4.49	0.161	3.23	1.41	7.40	0.006	2.96	1.19	7.39	0.020
Muscular strength training;												

≤ 1 sessions/week	0.86	0.30	2.43	0.774
2-4 sessions/week	1.00			
≥ 5 sessions/week	1.82	0.79	4.22	0.161
Aerobic fitness training;				
≤ 1 sessions/week	1.41	0.63	3.15	0.408

[a] Adjusted for confounding effect of sex and neck/shoulder pain previous to course start



Recruitment and measurement procedure, number of subjects included, excluded and weekly follow ups (wk.) during the marine training course. The main focus of the different phases of the course is given together with longer field exercises and leave periods. [a]One subject excluded from analysis based on LBP incidence, due to LBP at baseline that lasted for more than additional five course weeks. [b]DLL&L; Double Leg Lift & Lower test. [c]DLL&ALE; Double Leg Lift & Alternate Leg Extension.

77x28mm (600 x 600 DPI)

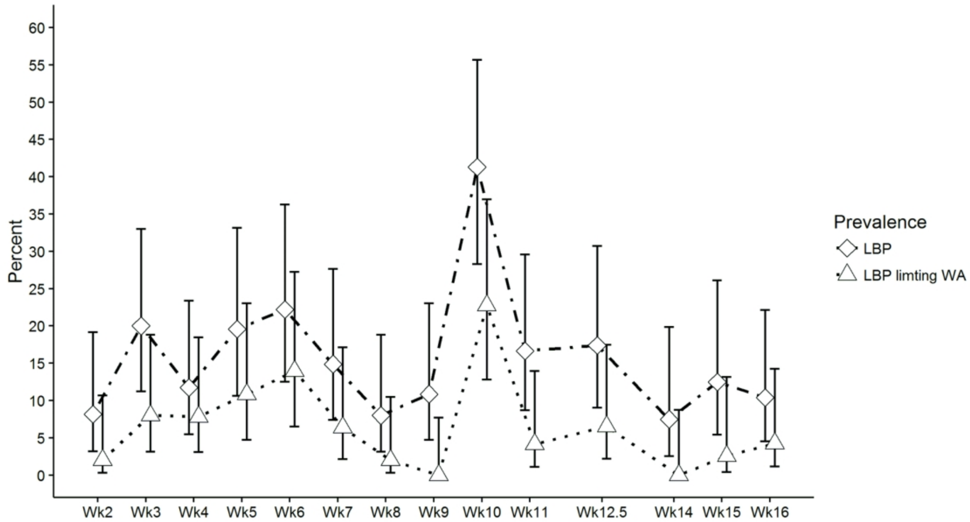


Figure 2. Weekly (Wk.) prevalence of LBP and LBP limiting work ability during the marine training course, reported as weekly proportion (percent) of cohort under study. Error bars indicate 95% confidence interval.

79x44mm (600 x 600 DPI)

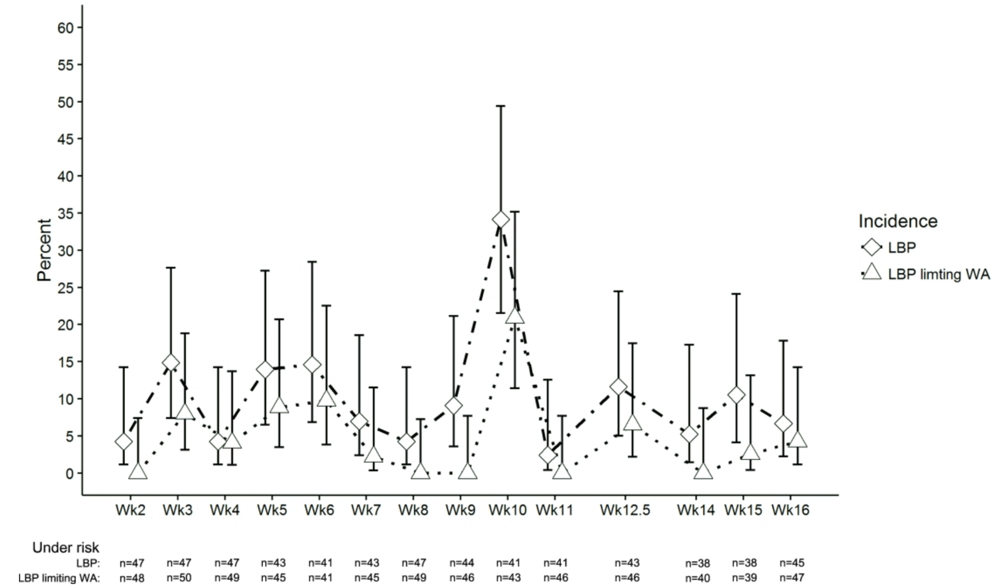


Figure 3. Weekly (Wk.) incidence of LBP and LBP limiting work ability during the marine training course, reported as weekly proportion (percent) of new pain episodes of marines at risk for a new event. Error bars indicate 95% confidence interval.

144x84mm (600 x 600 DPI)

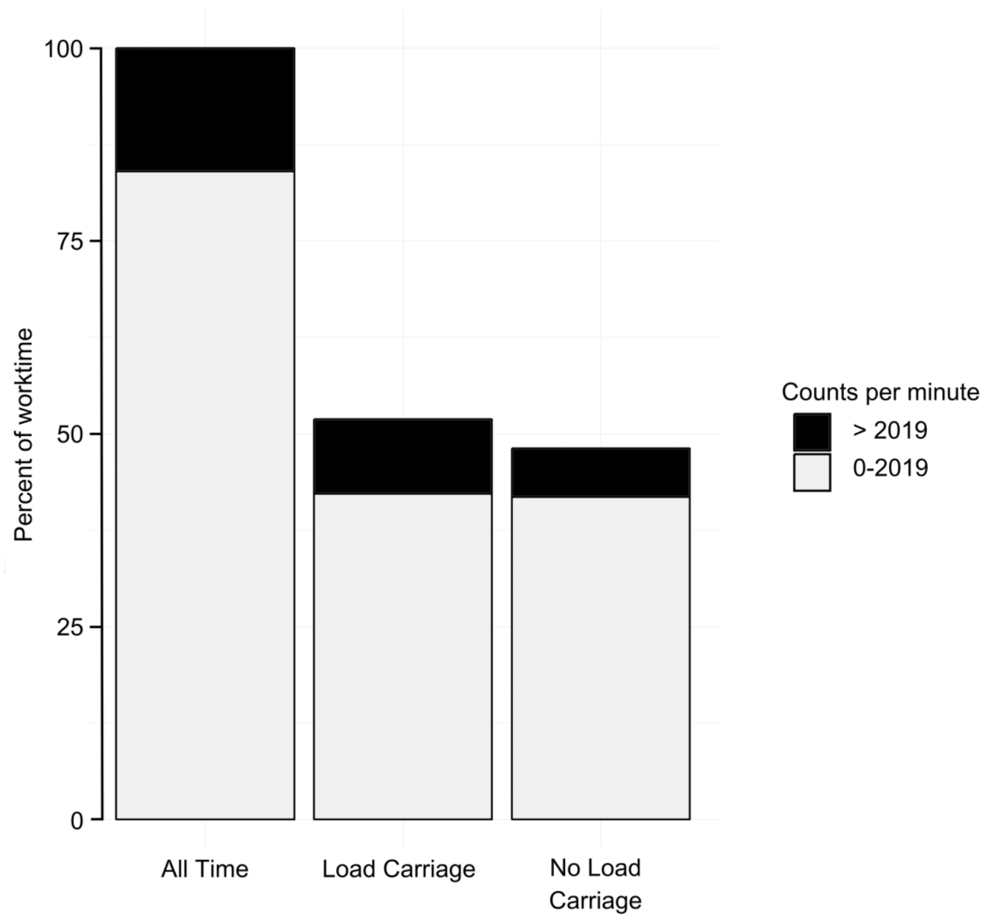


Figure 4. Proportions of work time spent in occupational physical activity generating more and less than 2020 counts per minute; in total, with, and without combat load carriage (≥17.5 kg). Work time is based on an average weekly work-time of 38 hrs (not including long distance march training, combat obstacle course or aquatic training, constituting a weekly average of an additional 2 hrs).

110x109mm (600 x 600 DPI)

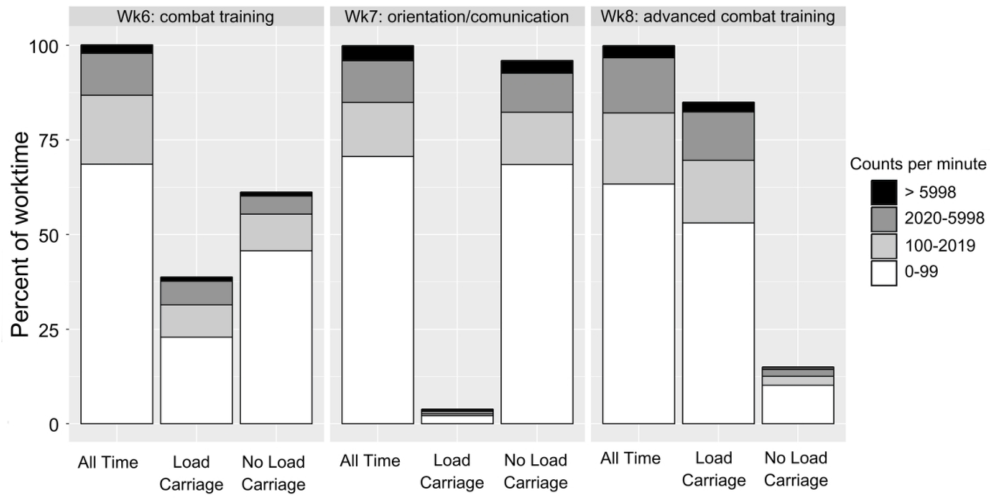


Figure 5. Proportions of work time in occupational physical activity reported per category of physical intensity (42), for total work time and time with/without combat load carriage (≥17.5Kg) for three consecutive course weeks with different learning objectives; "combat training (course week 6)", "orientation and communication (course week 7)" and "advanced combat training (course week 8)".

65x33mm (600 x 600 DPI)

Low back pain in the marine training course: A longitudinal observational study of back pain incidence, risk factors, and occupational physical activity in Swedish marine trainees

Supplementary Files

Supplementary Table 1. Incidence rate (IR) based on time to first LBP, and LBP limiting work-ability, episode during the marine training course.

	LBP			**LBP limiting work ability**		
	Time at risk	**IR**	**95%CI**	**Time at risk**	**IR**	**95%CI**
Per 100 person-weeks	398 person weeks	9.0	6.5-12.5	539 person weeks	3.9	2.5-6.0
Per 1000 person-days	2786 person days	12.9	9.3-17.9	3773 person days	5.6	3.6-8.5

Supplementary Table 2. Regression analyses of individual physical characteristics, work- and health-related risk variables: initial multiple hazard ratio (HR) for low back pain (LBP) and LBP limiting work ability during the marine training course.

Variable	LBP limiting work ability Initial Multivariable				LBP limiting work ability Initial Multivariable			
	HR	**95% CI**		**p value**	**HR**	**95% CI**		**p value**
Physical characteristics								
Body Height ≤1.80 (m)	1.69	1.02	2.79	0.040	2.90	1.31	6.43	0.009
Rated health/health history								
Back Pain; within 6 mo. prior to course start	1.61	0.85	3.05	0.145	2.42	0.89	6.55	0.082
Hip/Knee Pain; within 6 mo. prior to course start	1.30	0.75	2.27	0.350				
Neck/Shoulder Pain; within 6 mo. prior to course start	1.25	0.68	2.35	0.483	2.35	0.76	7.21	0.136
Work-related								
Current Work ability with regard to best ever	1.48	0.86	2.54	0.152				
Physical training habits past 6months								
Physical training;								
≤ 2 sessions/week					3.16	1.23	8.13	0.017
Muscular strength training;								
≤ 1 sessions/week					0.44	0.12	1.61	0.215
2-4 sessions/week								
≥ 5 sessions/week					1.27	0.45	3.54	0.649

Supplementary Table 3. Regression analyses of clinical tests: univariate and multiple final adjusted[†] hazard ratio (HR) for low back pain during the marine training course.

	Univariate				Final Adjusted Model[a]			
	HR	**95% CI**		**P value**	**HR**	**95% CI**		**P value**
Physical/clinical tests								
Kettlebell lifts; kg*rep								
≤760 (lowest tertile)	1.48	0.82	2.67	0.198				
Sensitivity analysis								
CC (i.e. only male)	*1.44*	*0.76*	*2.7*	*0.261*				
Imputed (only male)	*1.48*	*0.75*	*2.91*	*0.256*				
Pull-ups								
≤ 3	1.99	1.11	3.56	0.020	1.87	1.17	3.01	0.009
Sensitivity analysis								
CC (i.e. only male)	*2.00*	*1.10*	*3.66*	*0.025*	*1.82*	*1.16*	*2.88*	*0.009*
Imputed (only male)	*1.94*	*1.06*	*3.54*	*0.032*	*1.81*	*1.13*	*2.91*	*0.014*
MCM-Tests, direction specific;								
DLL-L Flex; *Fail*	0.82	0.39	1.75	0.613				
DLL-L Ext; *Fail*	0.82	0.47	1.46	0.508				
DLL-ALE Flex; *Fail*	0.71	0.32	1.56	0.388				
DLL-ALE Ext; *Fail*	1.35	0.76	2.40	0.310				

[a]Adjusted for prior back pain and body height

Abbreviations; CC; complete cases, DLL-L Flex; Double leg lift-lower lumbar flexion-control, DLL-L Ext; Double leg lift-lower lumbar extension-control, DLL-ALE Flex; Double leg lift-alternate leg extension lumbar flexion-control, DLL-L Ext; Double leg lift-alternate leg extension lumbar extension-control.

Supplementary Table 4. Regression analyses of clinical tests: univariate hazard ratio (HR) for low back pain limiting work ability during the marine training course.

	HR	95% CI		P value
Physical/clinical tests				
Kettlebell lifts; kg*rep				
*≤760 (*lowest tertile)	1.02	0.67	1.54	0.923
Sensitivity analysis				
Complete cases (i.e. only male)	*1.10*	*0.31*	*3.92*	*0.884*
Imputed (only male)	*1.12*	*0.37*	*3.39*	*0.834*
Pull-ups				
≤ 3	1.02	0.75	1.38	0.912
Sensitivity analysis				
Complete cases (i.e. only male)	*1.23*	*0.42*	*3.64*	*0.709*
Imputed (only male)	*1.29*	*0.46*	*3.60*	*0.631*
MCM-Tests, direction specific;				
DLL-L Flex; *Fail*	0.71	0.21	2.43	0.587
DLL-L Ext; *Fail*	0.85	0.35	2.06	0.715
DLL-ALE Flex; *Fail*	0.76	0.23	2.54	0.650
DLL-ALE Ext; *Fail*	0.71	0.29	1.73	0.452

Abbreviations; DLL-L Flex; Double leg lift-lower lumbar flexion-control, DLL-L Ext; Double leg lift-lower lumbar extension-control, DLL-ALE Flex; Double leg lift-alternate leg extension lumbar flexion-control, DLL-L Ext; Double leg lift-alternate leg extension lumbar extension-control.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page 1 and 2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 4
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 4-5
Methods			
Study design	4	Present key elements of study design early in the paper	Page 5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 5 and Fig.1
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Page 5 and 7
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Pages 7-8 and Table 1-2
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Table 1-2
Bias	9	Describe any efforts to address potential sources of bias	Page 8
Study size	10	Explain how the study size was arrived at	Page 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Table 1-2
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 8 and 9-10
		(*b*) Describe any methods used to examine subgroups and interactions	Page 10
		(*c*) Explain how missing data were addressed	Page 8-9
		(*d*) If applicable, explain how loss to follow-up was addressed	Pages 7,8 and Fig.1
		(*e*) Describe any sensitivity analyses	Page 9
Results			Page 10

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Page 5, Fig 1. and Fig.3
		(b) Give reasons for non-participation at each stage	Page 5, Fig 1. and Fig.3
		(c) Consider use of a flow diagram	Fig 1.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 5 and table 3
		(b) Indicate number of participants with missing data for each variable of interest	Page 8
		(c) Summarise follow-up time (eg, average and total amount)	Supplementary Table 1.
Outcome data	15*	Report numbers of outcome events or summary measures over time	Page 11, Fig. 2-3 and Supplementary Table 1.
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 10-11, Table 4-5 and Supplementary Table 3-4.
		(*b*) Report category boundaries when continuous variables were categorized	Tables 1 and 2
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Page 10-11, Supplementary Table 2-4.
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 11
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Pages 11-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 11-12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on	Page 15

		which the present article is based	

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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A longitudinal observational study of back pain incidence, risk factors, and occupational physical activity in Swedish marine trainees

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Abstract

Objectives: To evaluate the occurrence of LBP and LBP that limits work ability, to identify their potential early risks and to quantify occupational physical activity in Swedish Armed Forces (SwAF) marines during their basic four-month marine training course.

Design: Prospective observational cohort study with weekly follow-ups.

Participants: Fifty-three SwAF marines entering the training course.

Outcomes: Incident of LBP and its related effect on work-ability, and associated early risks. Occupational physical activity, as monitored using accelerometers and self-reports.

Results: During the training course, 68% of the marines experienced at least one episode of LBP. This yielded a LBP and LBP limiting work ability incidence rate of 13.5 (95% CI 10.4-17.8) and 6.3 (95% CI 4.2-10.0) episodes per 1000 person-days, respectively. Previous back pain and shorter body height (≤1.80m) emerged as independent risks for LBP (HR 2.5, 95% CI 1.4–4.3; HR 2.0, 95% CI 1.2–3.3, respectively), as well as for LBP that limited work ability (HR 3.6, 95% CI 1.4–8.9; 4.5, 95% CI 2.0–10.0, respectively). Furthermore, managing fewer than four pull-ups emerged as a risk for LBP (HR 1.9, 95% CI 1.2–3.0), while physical training of fewer than three sessions per week emerged as a risk for LBP that limited work ability (HR 3.0, 95% CI 1.2–7.4). More than 80% of the work time measured was spent performing low levels of ambulation, however, combat equipment (≥17.5 Kg) was carried for more than half of the work time.

Conclusions: Incidents of LBP are common in SwAF marines' early careers. The link between LBP and previous pain as well as low levels of exercise highlights the need for preventive actions early on in a marine's career. The role of body height on LBP needs further investigation, including its relationship with body-worn equipment, before it can effectively contribute to LBP prevention.

Strengths and limitations of this study

- The present unique prospective study design with weekly follow ups that is conducted early on in the marines' careers is believed to have a strong potential to fill knowledge gaps in LBP epidemiology in marine regiments and similar military units.

- The use of a repeated time-to-event regression method, with discontinued risk intervals, better reflects the recurrent nature of LBP, and makes more use of collected data than methods using single time-to-first events as an outcome.

- The definition of a new episode of LBP used in the present study does not distinguish between a new "uniquely" first event and a "symptom flare up" from a recurrent chain of events, which is a problem seen in most studies on back pain or other musculoskeletal pain problems.

- The results for the two physical "max" tests of pull-ups and kettle-bell lifts are limited to male marines only, as no female marines performed these tests.

Keywords: Back pain, longitudinal, military, musculoskeletal disorders, musculoskeletal injury, occupational exposure, physical test, prevention, work ability, work exposure.

Background

Low back pain (LBP) is an epidemiological and clinical problem; it is the leading cause of disability worldwide (1). Its nature is commonly recurrent and causes reduction in physical activity (2) and work ability (3). Societal groups associated with high levels of physical activity are indeed not spared musculoskeletal problems, and this includes highly trained military units. In fact, approximately 40% of Swedish Armed Forces (SwAF) marines on active duty experience LBP within a six-month period, and about half of these experience related limitations in work ability (4). This indicates that LBP could have a severe impact on the SwAF marines' operational readiness, as is seen internationally in marine units (5), which warrants preventive actions. Given the recurrent nature of LBP (6), preventive measures are a high priority and are believed to be most effective early in a marine's career. While the occurrence of and risk factors for musculoskeletal disorders in initial basic military training have been investigated (7, 8), the subsequent early phases of a marine's career have received less scientific attention; thus the need exists to address this gap in knowledge regarding risks for LBP in active-duty marines.

A high occurrence of musculoskeletal disorders is considered to be present by the SwAF occupational health personnel even during the four-month SwAF marine training course, where soldiers that have completed basic training are given their first marine-specific training. This physically demanding course focuses on marine-specific occupational tasks, including long range foot patrols with heavy equipment and assault operations from combat crafts (high-speed boats). Given the nature of this first and mandatory part of a marine's career, preventive measures at this stage could have a significant effect on the occurrence of future LBP in this group, and this has long been named a priority research topic in many military nations. Results gained from prospective studies in such communities, where occupational load and tasks are homogeneous and well known, have – we believe – great potential to fill knowledge gaps for further actions in defined military units.

Notably, medical examinations, health appraisals, and the evaluation of physical performance are basic routine procedures at the start of a military training course or before deployments. Information from such early examinations along with known risks from civilian contexts, such as a history of previous pain episodes (9, 10), physiological distress, or lifestyle factors (10, 11), has the potential to provide relevant risk information in operating activities. While low physical capacity and low performance on military physical fitness tests have previously been indicated as risks for LBP (12, 13), the screening of marines or similar elite units before entering the course with valid tests for their occupational exposures is not presently performed. New physical screening protocols have indeed been developed and introduced for other SwAF units, covering areas possibly related to the development of LBP in marines as well, for example lifting- and load-carrying capacities (14).

While detailed knowledge of LBP occurrence and associated risk factors constitutes the foundation for early prevention of LBP within this occupational group, such information has to be interpreted in relation to the occupational physical demands on marines. Here, objective monitoring of occupational physical activity during the marine training course could aid in the interpretation of identified risks. This study therefore aimed to prospectively evaluate the occurrence of LBP and its effect on work ability, as well as to identify potential early risks for such disorders in soldiers during the marine training course. Further aims were to quantify occupational physical activity and work-related exposure during the course.

Methods

Study design

This study used a prospective observational design with a cohort of SwAF marines entering the four-month marine training course. A screening program consisting of a self-administered questionnaire and a battery of physical tests was conducted at the start of the course, while pain occurrences were then followed up on a weekly basis. Occupational physical activity was continuously monitored with accelerometers worn during working hours for seven weeks of the course by a sub-cohort of participants; this was supplemented by platoon and individual logs of work tasks and physical training. All data collection was conducted at the 1st Marine Regiment, Stockholm, Sweden, between January and May, 2015. The study was approved in advance by the Regional Medical Research Ethics Committee, Stockholm (2014/1904-31/2). After receiving written and oral information on the study, signed informed consent was obtained from all participants prior to enrolment. Measurement occasions and the focus of the different phases of the course are illustrated in Figure 1, along with information on the participants' progression throughout the study.

Figure 1. about here

Patient involvement

Given the defined target group in the present study, no patients seeking medical care were recruited. The present research questions and outcomes are based on data/conclusions from our on-going translational research on active duty marines (4, 15); it is also influenced by our empirical knowledge and clinical work in this population. The Marines' medical and occupational health services have taken part in planning the data collection, and they constitute the primary way of implementing the results in clinical work for the studied population.

Participants

To be eligible for inclusion in the present study, marines had to have the intention to complete the entire marine training course. Of 56 eligible marines, 53 met the criterion, and were enrolled in the study. The mean (SD) age, body weight, height, and body mass index for the enrolled marines were: 21.8 (3.4) years, 80.0 (10.1) kg, 1.82 (0.07) m and 24.1 (2.5) kg/m^2, respectively. The majority of participants (91%, n=48) were men. Ten (19%) had experienced pain in the lower back within six months prior to baseline. Marines with on-going LBP at baseline lasting for five or more consecutive weeks adjacent to the course start (n=1) were excluded from analysis based on incidences.

Measurements and Procedure

Baseline questionnaires

Participants initially completed confidential questionnaires to elicit military and demographic background information (4), general health (16) and mental health (17), self-assessed work ability (16), and physical training habits. The questions, which are described in detail in Table 1, have previously been used in international and Swedish public health cohorts and studies of active duty SwAF marines. The questionnaires also included detailed information on musculoskeletal pain for nine anatomical areas (18) within the past week and six months, with the following reporting options: For pain within the past week *"No pain"* or *"Pain"* and for pain within the past six months *"No pain"*, *"Pain a couple a days per month or less",* or *"Pain a couple of days per week or more"*. Pain limiting work ability was assessed using the options *"Not limited"*, *"Limited to some extent",* or *"Limited to a large extent"*.

Table 1. Self-reported independent variables, the form in which they were included in regression analysis, procedures for retrieving the data and rationale for categorisation.

Independent variable	Reference	Exposure	Measurement procedure and variable management
Physical characteristics			
Body weight	Continuous		Body weight (in Kg) was self-reported and analysed as a continuous variable in the models.
Body Height	> 1.80m	≤1.80m	Body height was self-reported. Based on the hypothesis that being either "too tall or too short" may be negative for musculoskeletal health in this environment, as previously identified for this population (4), *body height* was initially categorised as ≤1.80m, 1.81-1.85m *(reference)* and ≥1.86m (representing body height tertiles of the SwAF marine population, (4, 15), but was reduced to a dichotomised variable due to no difference between the upper and the reference category being identified.
Rated health/health history			
Back Pain; within 6 mo. prior to course start	No	Yes	Self-reported musculoskeletal pain in the lower and/or thoracic back , defined as *"Pain a couple of days per month or less"* or *"Pain a couple of days per week or more"* within the past six months, analysed dichotomised as *yes* or *no* as previously for this population (4, 15).
Hip/Knee Pain; within 6 mo. prior to course start	No	Yes	Self-reported occurrence of musculoskeletal pain in the *hip* and/or *knee*, defined as *"Pain a couple of days per month or less"* or *"Pain a couple of days per week or more"* within the past six months, analysed dichotomised as *yes* or *no,* as previously for this population.
Neck/Shoulder Pain; within 6 mo. prior to course start	No	Yes	Self-reported musculoskeletal pain in the *neck* and/or *shoulder*, defined as *"Pain a couple of days per month or less"* or *"Pain a couple of days per week or more"* within the past six months, analysed dichotomised as *yes* or *no,* as previously in this population.
Mental distress (GHQ-12 Score)	<4	≥4	The level of mental distress was captured by the General Health Questionnaire-12 (19), a widely used screening instrument developed to detect "cases" of mental distress. It is a 12-

			question tool, summed up to give an overall score, ranging from 0 to 12, and a cut off of 4 points or more is considered an indication of clinically relevant mental distress (20). As such, "*Mental distress*" was categorised as ≥4 on the summary GHQ-12 scale.
Work related			
Current work ability with regard to best ever	≥9	<9	Self-rated work ability captured with the single item question from the work ability index (16). Current work ability was rated, with regard to ever best, on a 10-point ordinal scale. Based on the hypothesis that "less-than-optimal" work ability could constitute a risk in this environment, the responses were dichotomised as high (≥9) (*reference*) and moderate (<9).
Direct from basic military training (within 3 mo.)	No	Yes	Finishing basic military training within three months of the course start was considered a risk, due to the assumption that these soldiers had had less time to adapt to load carriage within the military. Therefore dichotomised as *yes* or *no (reference)*.
Physical training habits			
Physical training; sessions per week	>2 sessions /week	≤2 sessions /week	Average number of training sessions per week, exceeding 20 minutes, were rated on a five point ordinal scale as ≤1 day/week, 2 days/week, 3-4 days/week and ≥5 day/week. This item was derived (in addition to an increased number of maximum sessions) from items previously used in several public health cohorts in Sweden (21, 22). A U-shaped relationship with LBP was hypothesised for number of physical training sessions per week, i.e. too little and too much training may both be risks for LBP. Consequently, the training sessions per week variable was categorised as ≤2 session/week, 3-4 sessions/week (reference) and ≥5 sessions/week, but reduced to a dichotomised variable for LBP limiting work ability as no significant difference between the upper and reference category was found.
Muscular strength training; session per week	2-4 sessions /week	≤ 1 sessions /week ≥5 sessions	A U-shaped relationship with LBP was hypothesised for number of strength training sessions per week, i.e. too little and too much training may both be risks for LBP. Consequently *Weekly strength training* was categorised as ≤1 session/week, 2-4 sessions/week *(reference)* and ≥5 sessions/week.

		/week	
Aerobic fitness training; sessions per week	>1 session /week	≤ 1 sessions /week	*Weekly aerobic training* was dichotomised as ≤1 session/week or >1 *(reference),* given two session per week a priori considered to be a realistic minimal amount of cardio vascular training necessary to maintain sufficient aerobic capacity during the physically demanding basic military training course.

Physical baseline tests

Physical tests focusing on muscle strength and movement control were performed during the first ten days of the course. These tests, described in detail in Table 2, were selected on the basis of their use in clinical/preventive work among the studied population or in screening programs within the SwAF, and have previously been found reliable for use with active duty SwAF marines (23) or similar SwAF units (14). The strength tests, which were conducted following standardised SwAF instructions (14), were:

- *Kettlebell lifts* - The number of (correct) lifts of a pair of kettlebells (2 x 16, 24, or 32 kg) completed in a one-minute interval (14) and,
- *Pull-ups* - The number of (correct) pull-ups completed, performed hanging from a bar with an overhand (pronated) grip (14).

These tests were conducted within a series that also including a loaded lower limb functional test (24) (performed before these tests) and the ranger (loaded) step test (25) (performed after these tests), which are described in detail elsewhere (24, 25).

The two movement control tests were derived from the descriptions by Comerford and Mottram (26) and tested for good reliability in SwAF marines (23). These tests focus on the ability to actively control or prevent compensatory movement in the lumbar spine, i.e. flexion, extension or rotation, while actively moving the lower extremities. The tests, conducted following standardised instructions, (23) were:

- *Double Leg Lift & Lower (DLL&L):* The subject, from a supine position, lifts both feet off the bench to a 90° hip flexion, and then lowers them back to the bench. Any uncontrolled movements in flexion or extension were recorded in the test protocol.
- *Double Leg Lift & Alternate Leg Extension (DLL&ALE):* The subject, from a supine position, lifts both feet off the bench to a 90° hip flexion, then lowers and straightens one leg to a fully extended position and then back to a 90° hip flexion. The procedure was then repeated with the other leg, after which both legs were lowered to the starting position. The direction of any uncontrolled movements in extension, flexion, or rotation was recorded in the test protocol.

Table 2. Physical test; independent variables, the form in which they were included in regression analysis, procedures for retrieving the data and rationale for categorisation.

Independent variable	Reference	Exposure	Measurement procedure and variable management
Strength tests			
Kettlebells lift; kg x repetitions	> 760	≤760	Pairs of kettlebells weighing 32, 24, or 16 kg each were used. The intended test weights were 2x32 kg, but subjects unable to perform the test safely with these loads could choose the lighter kettlebells. To make sure that the correct and safe lifting technique was used, all participants performed two test-lifts using a lower weight while being supervised by the test leader. The test measured the number of (correct) lifts of the weights performed in one minute. Based on the assumption that marines with the lowest lifting capacity are at greater risk of LBP, the lower tertile of the product of "numbers of lifts x weight lifted" was compared to the upper two tertiles (reference).
Pull-up; number of repetitions	≥ 4	≤ 3	Hanging from a pull-up bar, using an overhand grip with hands placed shoulder-width apart, the participants lifted their body until their chin was level with the bar. The number of (correct) lifts performed in one minute was recorded in the test protocol. The number of correct 'chins' is dichotomised as ≤3 or ≥4 *(reference)*. Internationally, the cut-off for passing a pull-up test during yearly physical assessments for marines ranges from 3 (US marines) to 5 (Royal Marines) and as such, assuming that marines with the lowest pull-up capacity are at greater risk of LBP, the cut-off for the reference category was set at the median, ≥4 pull-ups (*reference*).
Movement control tests			*To make sure failure of any of the movement control tests was due to a "real" inability to control direction and not unfamiliarity with the test movement, all participants performed the test three to six times with feedback from the tester to ensure familiarisation. To monitor the movement of the lumbar spine, an air-filled pressure sensor (Pressure Biofeedback Unit, Chattanooga Group, Hixon, TN) was placed under the lower back.*
Double Leg	pass	fail	The test assesses the ability to prevent extension and flexion of the lumbar spine (26). The subject,

Lift & Lower			from a supine position, lifts both feet off the bench to a 90° hip flexion, and then lowers them back to the bench. Any uncontrolled movements in flexion or extension, defined as an ≥5mmHg change (from the starting pressure of 40mmHg), were recorded on the test protocol. Test performance on *flexion* and *extension* assessed in the tests was analysed as pass or fail.
Double Leg Lift & Alternate Leg Extension:	pass	fail	The test assesses the ability to prevent extension, flexion and rotation of the lumbar spine, and leg abduction, lateral rotation, and hip forward glide (26). The subject, from a supine position lifts both feet off the bench to a 90° hip flexion, then lowers and straightens one leg to a fully extended position and then back to a 90° hip flexion, before repeating the test on the other side. The direction of any uncontrolled movements, defined as ≥5mmHg change (from the starting pressure of 40mmHg), was recorded on the test protocol. Test performance for *flexion* and *extension* assessed in the tests was analysed as pass or fail.

Continuous assessment of work-related physical activity and occupational tasks

Twenty-seven marines from the inception cohort were randomly assigned by a computer-generated algorithm to wear accelerometers during the course. Six declined, leaving 21 marines in this sub-cohort. They were fitted with tri-axial accelerometers (GT3X+BT, Actigraph, Pensacola, FL) and instructed to wear them on the left hip during all working hours of the course, with the exception of planned prolonged loaded marches (due to the risk of interaction with back pack hip belts resulting in abrasions or compression injuries), aquatic physical training, or during training conducted at the marine combat obstacle course (due to water obstacles). They were also instructed to remove them during field exercises conducted at other bases during weeks 11-13 of the course due to an inability to collect data at these locations. The accelerometers were initialised using ActiLife software (version 5.5), with data sampling set at a rate of 30Hz. Information on occupational tasks and equipment worn, and physical training sessions conducted, was recovered from detailed weekly schedules completed by the instructing officers, as well as from the self-reported diaries kept by the marines.

Weekly follow-up

Incidence of musculoskeletal disorders and related effect on work ability were self-reported weekly during the course, using a short version of the baseline questionnaire. The number of responders for each week is illustrated in Figure 1. Weekly follow-ups were not strictly possible due to the geographic location of training during course week 12, so the follow up was conducted at the beginning of week 13 and reported as week 12.5 (i.e. week 12 and half of week 13).

Outcomes

LBP was defined as the occurrence of any self-rated pain in the lower back (from the twelfth ribs to the lower gluteal folds (27) within the preceding week, as reported during the weekly follow-up. LBP limiting work ability was defined as the occurrence of any self-rated pain in the lower back within the preceding week that had limited work ability.

For incidence proportions, rates, and regression analysis (described in detail below), marines were considered to be at risk for an event as long as they were under observation, and until the occurrence of a LBP event. At the time of pain occurrence, the risk interval was discontinued and marines were not considered to be at risk for a new episode until they were pain free for the next coming week (if reporting no pain in that week, it was counted, if reporting pain also that week, the week remained censored). Meeting this requirement automatically allowed them to re-enter the analysis (pain observation period). Marines with on-going LBP at baseline were not considered at risk until they were pain free for at least one week, at which point in time they entered the analysis. Late entry was only allowed during the first four weeks to accurately reflect the independent variables collected at baseline.

Independent variables

Independent variables analysed as potential risk factors for LBP and LBP limiting work ability were selected based on existing evidence from active-duty SwAF marines, other military and civilian populations, and empirical knowledge from clinical work with the SwAF marines. These 17 variables, including two physical characteristics, four health-related, two work-related, three on physical training habits, and the results of the two strength and the two movement control tests (in flexion and extension), are described in detail in Table 1 and 2.

Confounding variables

Age, *BMI*, *sex*, *smoking*, *non-musculoskeletal co-morbidity,* and *LBP previously during the course* were a priori considered possible confounders. A confounder was defined as a variable that, when included during the analytic process, changed the hazard ratio of the crude regression model >20% (28).

Data management and statistics

Missing data

The dependent variables, i.e. LBP and LBP limiting work ability, were missing for 11% of the data due to subjects' lost to follow-up during the course. Also, of the independent variables, the kettlebell lift tests were missing for 30%, the pull-ups 23%, and the DLL-ALE test 4%, due to participants not being able (or allowed) to perform the test at baseline (illness such as having a cold or other infection in 44% of these and pain or similar co-morbidity in 56%). All female marines (n=5) missed the kettlebells lift and the pull-ups tests due to illness or on-going pain. Based on the analysis of the missing data mechanism (29), however, the data for outcomes and the DLL-ALE test were considered to be "missing completely at random" (i.e. the reason for data to be missing was not dependent of the missing data itself nor predicted by the independent variables included the analysis) and missing data on the kettlebell lift and the pull-ups tests to be "covariate missing completely at random" (missing data predicted by bodyweight and body height). Multiple imputations by Markov chain Monte Carlo, with random draws based on Jeffreys prior distribution, were used to generate 50 imputed datasets with completed data on all predictor variables, on which the pooled analyses were based (30). Given that no female marines performed the two strength tests, imputing values for females based on data from only male marines on these tests might affect the accuracy of the imputation. Therefore, regressions including these two tests were repeated, as part of the sensitivity analysis, on only complete cases, as well as on multiple imputed data with females excluded.

Descriptive statistics

LBP and LBP limiting work-ability

Weekly prevalence was analysed as a percentage of those under observation, with 95% CI (31). Weekly incidence of LBP and LBP limiting work ability was analysed as a percentage of those at risk, with a 95% CI (31). The incidence rate of LBP and LBP limiting work ability during the course was calculated based on the number of episodes and the time at risk, presented as episodes per 1000 person-days, with a corresponding 95% CI (32).

Work-related physical activity and occupational tasks

Accelerometer data were analysed only if sufficient wear time could be established, which was defined as at least 180 minutes of wear time per day (for full work days) on at least three workdays (for a five-day week). Non-wear time within days was identified by algorithms suggested by Choi (33). For valid wear-time, vertical counts per minute (cpm; where the arbitrary unit of counts is the filtered raw acceleration generated by body movements and captured by the accelerometer) - based on 10-second epochs - were extracted and reported as minutes and percentage of total work time, and work time per week spent in these predefined categories: 0-99; 100-2019; 2020-5998; and 5999- cpm (34). Here, the category of 2020-5998 cpm was considered to be comparable to slow to brisk walking (~3.8-7.5 km/h) (35, 36). In addition, the percentage of the workday spent in these categories was reported for time with and without load carriage (combat equipment, ≥17.5 Kg), as identified from the detailed schedules (verified against activity logs). Evaluation and comparison with work schedules were performed visually.

Regression analysis

We used the Andersen-Gill repeated time-to-event regression method (37, 38) with the robust sandwich variance estimator (39), and discontinuous risk intervals (38), as defined above, to examine the predictive association between the independent variables and LBP. The results are reported as hazard ratios (HR) with a corresponding 95% CI. Secondly, this method was applied to examine the predictive association between independent variables and LBP limiting work ability.

Independent variables were analysed in two blocks. First, *physical characteristics, work- and health-related* variables, as identified with univariate time-to-event regressions to be associated with the dependent variable, at the level of $p<0.20$, were included in a multivariable time-to-event regression model. This was followed by an iterative, purposeful selection process of deleting non-significant variables at $p>0.05$. The model was then refitted and verified until a final model contained only significant ($p<0.05$) independent variables, identified confounders, and significant ($p<0.05$) interactions (between independent variables in the final model and/or independent variables and confounders) (28). This process was repeated for the *clinical tests*, with the addition of the significant *physical characteristics, work- and health-related* risk factors addressed as additional potential confounders. Due to the relatively small sample size, the confidence interval for borderline significant independent variables was inspected (i.e. inspection of the lower limit confidence interval in relation to the size of effect estimate) for indications of incorrect omission from final models (40). All final models were deemed to have sufficient confidence interval coverage, based on the events-per-variable ratio (40). Using methods described by Cleves et al. (41), final models showed no violations of underlying assumptions of proportional hazards (e.g. tests based on reestimation, interaction of analysis time with the independent variables and graphically through Schoenfeld residuals) and showed appropriate model fit. Analysis was performed using STATA Statistical software (version 13.1; College Station, TX).

Results

Table 3 presents demographic and background data as well as self-rated general health for the 53 marines who completed the baseline questionnaire (96% response rate). Good or excellent current health status was reported by >95% of respondents. Of the 53 marines starting the course, 49% joined directly from basic military training, while the other 51% came from previous service in the SwAF or from a period of civilian occupation/studies.

Table 3. Demographic characteristics, physical characteristics and self-rated health at baseline.

	Mean	**SD**
Age (years)	21.8	3.4
Body weight (kg)	80.0	10.1
Body height (m)	1.82	0.07
Body mass index (kg/m^2)	24.1	2.5
GHQ-12 Score	1.8	1.6
Muscular strength training; hours per week[a]	4.5	2.7
Aerobic fitness training; hours per week[b]	3.1	1.9
	%	**95% CI**
Smoking		
No	71.7	58.4-82.0
Occasionally	28.3	18.0-42.6
Yes	0.0	0.0-6.8
Snus (smokeless tobacco)		
No	64.2	50.7-75.7
Occasionally	11.3	5.3-22.6
Yes	24.5	14.9-37.6
Baseline testing	**Mean**	**SD**
Pull-ups	7.8	5.2
Kettlebell lifts		
Average lifts	17.6	6.4
Kettlebell, average weight (x2)	29.8	4.1
	%	**95% CI**
MCM-Tests, per direction;		

DLL-L Flex; Fail	19.2	10.8-31.9
DLL-L Ext; Fail	34.6	23.2-48.2
DLL-ALE Flex; Fail	19.6	11.0-32.5
DLL-ALE Ext; Fail	43.1	30.1-56.7

Note: Reported with mean and standard deviation (SD) or percentage and corresponding 95% Wilson Score confidence interval (95% CI).

[a]Average weekly hours of muscular strength training during previous six months (median (interquartile range) all; 4(3.5), males; 4(3.5), females 3(3)).

[b]Average weekly hours of aerobic fitness training during previous six months (median (interquartile range) all; 3(2), males; 3(2), females 5(3)).

LBP and LBP limiting work-ability

Figures 2 and 3 present the prevalence and incidence of LBP and LBP limiting work ability, expressed per week during the marine training course. A total of 68% of the marines experienced at least one episode of LBP during the course, of whom 57% reported related limitations in their ability to work. The average LBP episode consisted of 1.6 weeks of reported pain, with 42% of the sufferers experiencing at least one recurrent episode (with an average of 2.8 weeks without reporting pain between episodes). This gave an LBP incidence rate of 13.5 (95% CI 10.4 to 17.8) episodes per 1000 person-days. For LBP limiting work ability the corresponding incidence rate was 6.3 (95% CI 4.2 to 10.0). For comparison, incidence rates based on time to first event (during the course) are presented in supplementary Table 1.

Fig. 2 and 3 about here.

Risk factors for LBP and LBP limiting work ability

Individual physical characteristics, work- and health-related risk factors

Tables 4 and 5 present the results from univariate, final unadjusted and final adjusted multivariable recurrent-event regression models for LBP and LBP limiting work ability during the course. *Back pain (lumbar* and/or *thoracic back pain)* within six months prior to the MTC and *shorter body height (≤1.80m),* adjusted for the confounding effect of *sex* (LBP and LBP limiting work ability) and *previous neck shoulder pain* (LBP limiting work ability), were identified as independent risks. Additionally, *less than three sessions per week of physical training* was a significant risk for LBP that limited work ability. No interactions between the independent variables, nor with the confounders, emerged as significant in any of the models. Inspecting the 95% CI of excluded variables did not indicate any non-correct exclusion of potential risk factors. For comparison, initial multiple models for LBP and LBP limiting work ability are presented with 95% CI in supplementary Table 2.

Table 4. Regression analyses of individual physical characteristics, work- and health-related risk variables: univariate and multiple final adjusted[†] hazard ratio (HR) for low back pain (LBP) during the marine training course.

Variable	Univariate				Final Crude Multivariable				Final Adjusted Multivariable[a]			
	HR	**95% CI**		**p value**	**HR**	**95% CI**		**p value**	**HR**	**95% CI**		**p value**
Physical characteristics												
Body weight (kg)	1.01	0.99	1.03	0.441								
Body Height ≤ 1.80 (m)	1.48	0.84	2.58	0.172	1.73	1.03	2.92	0.040	1.98	1.19	3.29	0.009
Rated health/health history												
Mental distress (GHQ-12 Score)	2.08	0.65	6.70	0.219								
Back Pain; within 6 mo. prior to course start	2.00	1.09	3.64	0.025	2.26	1.27	4.03	0.006	2.47	1.41	4.31	<0.001
Hip/Knee Pain; within 6 mo. prior to course start	1.50	0.85	2.66	0.163								
Neck/Shoulder Pain; within 6 mo. prior to course start	1.63	0.91	2.90	0.098								
Work-related												
Current Work ability with regard to best ever	1.69	0.97	2.94	0.064								
Direct from basic military training (within 3 mo.)	1.08	0.62	1.91	0.779								
Physical training habits past 6 months												
Physical training;												

≤ 2 sessions//week	1.18	0.53	2.64	0.692
3-4 sessions/week	1.00			
≥ 5 sessions//week	1.29	0.70	2.37	0.418
Muscular strength training;				
≤ 1 sessions/week	0.90	0.52	1.54	0.690
2-4 sessions/week	1.00			
≥ 5 sessions/week	1.27	0.58	2.78	0.542
Aerobic fitness training;				
≤ 1 session/week	1.24	0.66	2.36	0.502

[a] Adjusted for confounding effect of sex

Table 5. Regression analyses of individual physical characteristics, work- and health-related risk variables: univariate and multiple final adjusted[†] hazard ratio (HR) for low back pain (LBP) limiting work ability during the marine training course.

Variable	Univariate				Final Crude Multivariable				Final Adjusted Multivariable[a]			
	HR	**95% CI**		**p value**	**HR**	**95% CI**		**p value**	**HR**	**95% CI**		**p value**
Physical characteristics												
Body weight (kg)	1.00	0.96	1.04	0.991								
Body Height ≤1.80 (m)	2.20	0.96	5.03	0.062	3.04	1.35	6.86	0.007	4.48	2.01	9.97	<0.001
Rated health/health history												
Back Pain; within 6 mo. prior to course start	2.48	1.04	5.91	0.040	4.47	1.80	11.11	0.001	3.58	1.44	8.90	0.006
Hip/Knee Pain; within 6 mo. prior to course start	1.15	0.41	3.23	0.784								
Neck/Shoulder Pain;	2.79	1.18	6.57	0.019								

within 6 mo. prior to course start												
Work-related												
Current Work ability with regard to best ever	1.74	0.68	4.40	0.246								
Direct from basic military training (within 3 mo.)	1.71	0.73	4.00	0.218								
Physical training habits past 6 months												
Physical training;												
≤ 2 sessions/week	1.87	0.78	4.49	0.161	3.23	1.41	7.40	0.006	2.96	1.19	7.39	0.020
Muscular strength training;												
≤ 1 sessions/week	0.86	0.30	2.43	0.774								
2-4 sessions/week	1.00											
≥ 5 sessions/week	1.82	0.79	4.22	0.161								
Aerobic fitness training;												
≤ 1 sessions/week	1.41	0.63	3.15	0.408								

[a] Adjusted for confounding effect of sex and neck/shoulder pain previous to course start

Clinical tests

Performing fewer than four pull-ups (HR 1.9, 95% CI 1.2–3.0), adjusted for confounding effect of *previous BP* and *body height*, was identified as a significant risk for LBP. However, no clinical tests were associated with LBP limiting work ability at $p<0.05$. Final unadjusted and adjusted models for LBP limiting work ability are presented in Supplementary Tables 3 and 4. Sensitivity analysis based on complete cases and imputed data, with only males, caused only marginal changes in the results, with no effect on inference.

Work-related physical activity and occupational tasks

Of the seven weeks of measurement, five contained sufficient wear time that could be fully used for analyses. During these weeks, an average of 16% of the working time (73 minutes per day) (not including long-distance march training, combat obstacle course or aquatic training, with a weekly average of additionally 2 hrs), was spent in physical activity of at least moderate intensity, i.e. 2020-5998 cpm, or slow-to-brisk walking (~3.8-7.5 km/h). On average, four percent of total working time was spent in physical activity of at least vigorous intensity, i.e. >5998 cpm. Sixty-one percent (44 min. per day) of the time spent in activities generating >2020 cpm was conducted wearing combat equipment (≥17.5 kg), as illustrated in Figure 4. There was, however, a large variation across weeks in work-time wearing combat equipment that spanned from 4% to 94%, as exemplified in Figure 5.

Discussion

This prospective cohort study aimed to lay the foundation for LBP prevention in Swedish marines, by evaluating the occurrence of LBP and identifying early risks for such disorders in soldiers during the marine training course. The results showed a high occurrence of LBP and consequent limitations in work ability while participating in their basic training marine-course. Marines with a history of previous back pain, those with shorter body height, or marines who performed poorly in the pull-up test were twice as likely to experience a new episode of LBP during this four-month period of physically demanding marine tasks.

This study followed 95% (n=53) of the participants enrolled in a typical marine training course in the Swedish Armed Forces (SwAF). Our cohort was homogeneous with regard to demographic characteristics and occupational tasks, which is similar to previous studies of marines (4), and may be regarded as a representative military-marine sample. While the sample size constituted the majority of the eligible Swedish marine trainees, caution has been taken to avoid over-fitting of statistical models. The effect of the relative small sample size on precisions of the estimate was here reflected in the somewhat wide confidence intervals. Furthermore, given the heightened risk of non-identification of a true risk factor, omission of borderline significant risks, i.e. not reaching significance in the present study, should not exclude them for further investigation in other similar cohorts in the military community. The loss of power could have been avoided by including data from future training courses (i.e. accumulating a larger sample), other military courses, or by prolonging the follow up period (i.e. including time after the course) (42). For the present study's aims, however, we believe it was more important to emphasize sample homogeneity and specific work-related exposure, as we believe this to be one of the most challenging factors to control for in studies of military populations.

We believe this study to be the first to use a repeated time-to-event regression method, with discontinued risk intervals, for LBP in a military population. This method may – we believe – better reflect the recurrent nature of LBP and make more use of the collected data than the conversional methods using time-to-first event. The definitions of a new event vary between studies (43), but a pain-free period of one week was considered sufficient for an additional event to be defined as either a new event or symptom “flare up” (44) from a previous event. Given that this definition does not distinguish between a new “uniquely” first event or symptom “flare up” from a recurrent chain of events, potential differences in the mechanism for new and recurrent pain could not be further disentangled in this study. Regarding our baseline testing, marines that were injured (n=9) or ill (n=7) were not allowed to perform the “max effort” tests, because of the risk of worsening their health. However, analysis based on complete cases, as well as on imputations including only males, did not change the results, indicating an appropriate inference from the present results. Due to none of the female marines conducting the two “max” tests of pull-ups or kettle-bell lifts, these results should only be extended to males.

Our results show a relatively high incidence of LBP in this cohort of young marines, with more than two thirds experiencing at least one LBP episode during the course. This is almost twice the reported six-month LBP prevalence for active duty SwAF marines (4), more than twice the LBP incidence in the British combat infantryman’s course (45), and higher than the total musculoskeletal injury incidence in other military training cohorts (46-48). This difference in pain occurrence may partly be explained by differences in the length of follow-up periods (49), or how LBP was defined (50). However, the recall period in this study was relatively short, and as such should limit the risk of recall bias. Given that three of five marines experiencing LBP also reported related limitations in work ability, it is likely that LBP reduced the intended goals with the course, and this may have future negative effects on the operational readiness of SwAF marine units.

Although previous musculoskeletal disorders are considered to be the strongest predictor for new musculoskeletal disorders in military populations (15, 47, 51, 52), it is not clear if such previous pain-episodes are anatomically region-specific in their prediction. This might not make a substantial difference in general primary prevention policy decisions, but the present findings could – we believe – help clinicians to be more specific in their selection of suitable secondary preventive measures for LBP. However, until the pathophysiological pathways between prior and future pain episodes are further disentangled, this does not inform the clinician what specific deficiencies to address. As such, the current use is limited to identifying persons at risk of LBP (53); marines at risk should be considered for further clinical examination and secondary preventive action. The same goes for marines with a body height of ≤1.80m, here identified as a risk for both LBP and LBP limiting work ability. While risks associated with body height are in line with our previous results (4), it is not likely that a short body height per se constitutes the actual risk, it could potentially represent an interaction with equipment worn or specific work tasks conducted.

The present results also highlight the need for regular physical training (≥ 3 sessions/week) for military personnel planning to attend the marine training course. This is in line with recommendations for general health in the civilian population (54), and should certainly be stressed for this physically active military community as well. Here, inferior upper-body strength, as tested by the pull-up test, seems to have played a role in back pain aetiology. This test, used in different forms in many military physical assessments (14, 55), is considered a relevant test of the ability to navigate over obstacles (14), but also as a proxy for general upper-body strength and muscle endurance (56). The test primarily challenges the back, shoulder and arm muscles, but also to a moderate extent the external oblique and erector spinae muscles (57). As such, it could represent a valid test for marines as upper body strength is crucial for load carriage (58). No female marines conducted these tests, therefore future cut-offs need to be validated for them. Neither the kettlebell lifts nor any of the movement-control tests predicted future LBP, however, "core-strengthening exercises" were already conducted as part of the marines' daily calisthenics in this sample, potentially preventing such deficits early in the course. Still, the results tally with our previously reported results from active duty marines, where these tests, analysed as overall pass/fail, failed to predict back pain within a six- and 12-month event window (15). While the present study aimed at identifying early risks for LBP, the sample size limited the exploration of potential effect measures modification in the final models to two-way statistical interactions. These analyses did, however, not provide any evidence of previous back pain affecting the amount of physical training and upper body strength in relation to a new back pain episode. The direction of temporality could however only be addressed for the six months preceding the course start. Still, physical training is recommended as primary (59-64), secondary (59, 60, 62, 64), and tertiary (59-64) preventive actions for back pain in both general populations and occupational settings. This highlights the potential role of physical training as a preventive action against future back pain episodes for marines displaying these identified risks.

While the physical demands of the course could be one reason for high LBP incidence, more than eighty percent of the work time measured was spent at low levels of ambulation, i.e. producing less than 2020 cpm. These results were similar to, or lower than, ambulatory movements reported for basic military training courses (65-67). However, in comparison with the US basic military training, where loads of no more than 4.5 kg were carried for 80% of the time (65), the marines in the present study carried combat equipment weighing >17.5 kg for more than half of the measured work time. In addition, the maximum weight of equipment worn on certain occasions, such as during loaded marches, can at times be more than twice that. Considering that both body-worn equipment and load carriage has been linked to LBP in deployed military personnel (12), this may possibly relate to the high LBP incidence in the present study. Furthermore, it highlights the need to consider load carriage when examining the association between ambulatory movement and LBP in the military context.

In summary, LBP and related limitations in work ability are common during the four-month physically demanding marine training course, and may affect the future operational readiness of marine units. Since previous LBP episodes are the most consistent risk for further LBP, marines entering the course with a history of LBP should receive tailor-made secondary preventive actions. Furthermore, marines with few weekly sessions of physical training, or with insufficient upper body strength, should be considered for targeted physical training. Further investigation on the role of body height on LBP is needed, including its relation to body-worn equipment, before it can be effectively used in LBP prevention. In addition, while ambulation was low for parts of the course, combat equipment was carried for more than half of the work time, further indicating the need to consider the role of body-worn equipment in LBP aetiology for this population.

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Contributorship statement

AM was the main writer of the paper and participated in the conception and design of the study, and acquired, analysed and interpreted the data. HL and HN participated in the conception and design of the study, planning of the analysis, interpretation of the data as well as the writing and revising of the paper. MD was involved in the design and planning of the study, as well as interpreting the data and revising the paper. As senior project researcher, BOÄ participated in the conception and design of the study, planning the analysis and interpretation of the data, and writing and revising the paper. All the authors have read and approved the final manuscript.

Competing interests

Dr. Monnier reports grants from The Swedish Society for Military Medical Officers, grants from Ann-Mari och Ragnar Hemborgs Minnesfond, grants from Stiftelsen fond till minne av ömsesidiga Olycksfallsförsäkringsbolaget Land och Sjö, during the conduct of the study; Dr. Larsson has nothing to disclose. Dr. Nero has nothing to disclose. Dr. Djupsjöbacka has nothing to disclose. Dr. Äng has nothing to disclose.

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Data sharing statement

No additional data are available.

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Figures

Figure 1. Recruitment and measurement procedure, number of subjects included, excluded and weekly follow ups (wk.) during the marine training course. The main focus of the different phases of the course is given together with longer field exercises and leave periods.

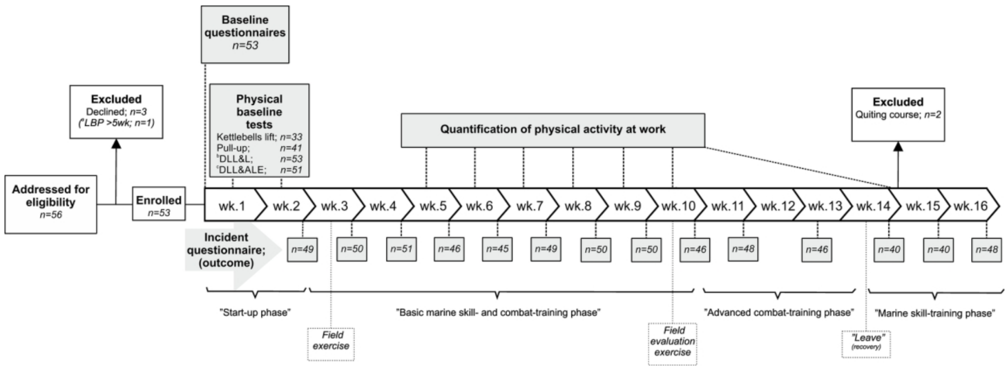
[a]One subject excluded from analysis based on LBP incidence, due to LBP at baseline that lasted for more than additional five course weeks. [b]DLL&L; Double Leg Lift & Lower test. [c]DLL&ALE; Double Leg Lift & Alternate Leg Extension.

Figure 2. Weekly (Wk.) prevalence of LBP and LBP limiting work ability during the marine training course, reported as weekly proportion (percent) of cohort under study. Error bars indicate 95% confidence interval.

Figure 3. Weekly (Wk.) incidence of LBP and LBP limiting work ability during the marine training course, reported as weekly proportion (percent) of new pain episodes of marines at risk for a new event. Error bars indicate 95% confidence interval.

Figure 4. Proportions of work time spent in occupational physical activity generating more and less than 2020 counts per minute; in total, with, and without combat load carriage (≥17.5 kg). Work time is based on an average weekly work-time of 38 hrs (not including long distance march training, combat obstacle course or aquatic training, constituting a weekly average of an additional 2 hrs).

Figure 5. Proportions of work time in occupational physical activity reported per category of physical intensity (42), for total work time and time with/without combat load carriage (≥17.5Kg) for three consecutive course weeks with different learning objectives; *"combat training (course week 6)"*, *"orientation and communication (course week 7)"* and "*advanced combat training (course week 8)"*.



Recruitment and measurement procedure, number of subjects included, excluded and weekly follow ups (wk.) during the marine training course. The main focus of the different phases of the course is given together with longer field exercises and leave periods. [a]One subject excluded from analysis based on LBP incidence, due to LBP at baseline that lasted for more than additional five course weeks. [b]DLL&L; Double Leg Lift & Lower test. [c]DLL&ALE; Double Leg Lift & Alternate Leg Extension.

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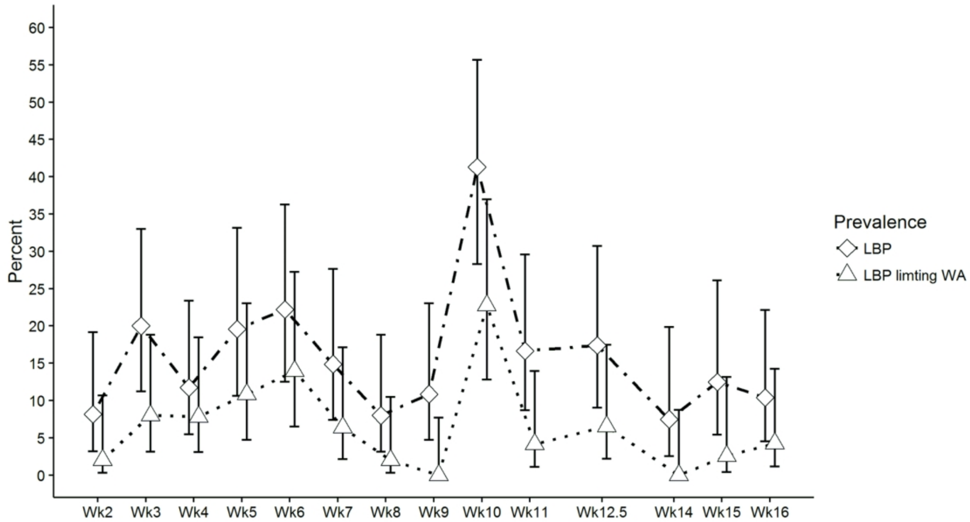

Figure 2. Weekly (Wk.) prevalence of LBP and LBP limiting work ability during the marine training course, reported as weekly proportion (percent) of cohort under study. Error bars indicate 95% confidence interval.

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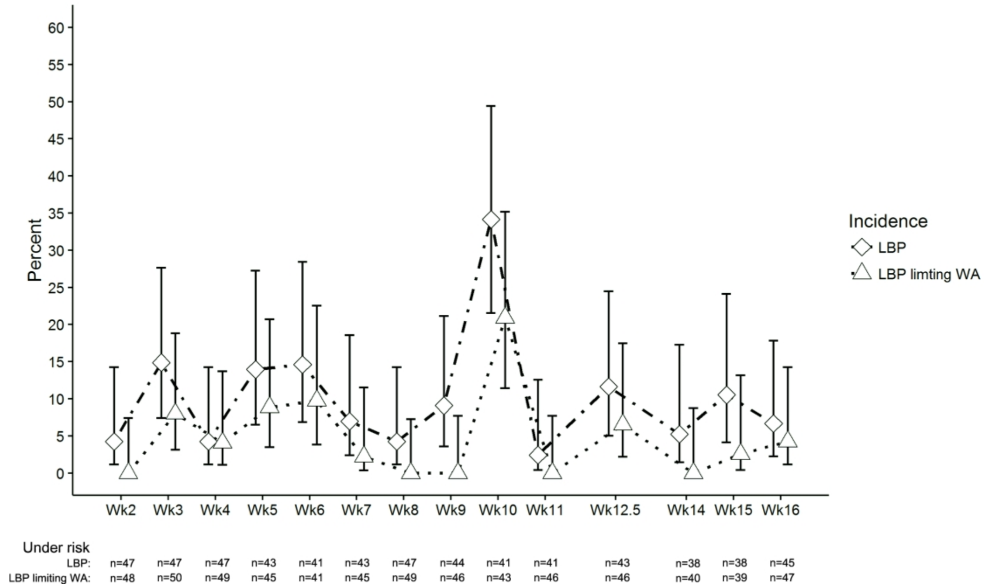

Figure 3. Weekly (Wk.) incidence of LBP and LBP limiting work ability during the marine training course, reported as weekly proportion (percent) of new pain episodes of marines at risk for a new event. Error bars indicate 95% confidence interval.

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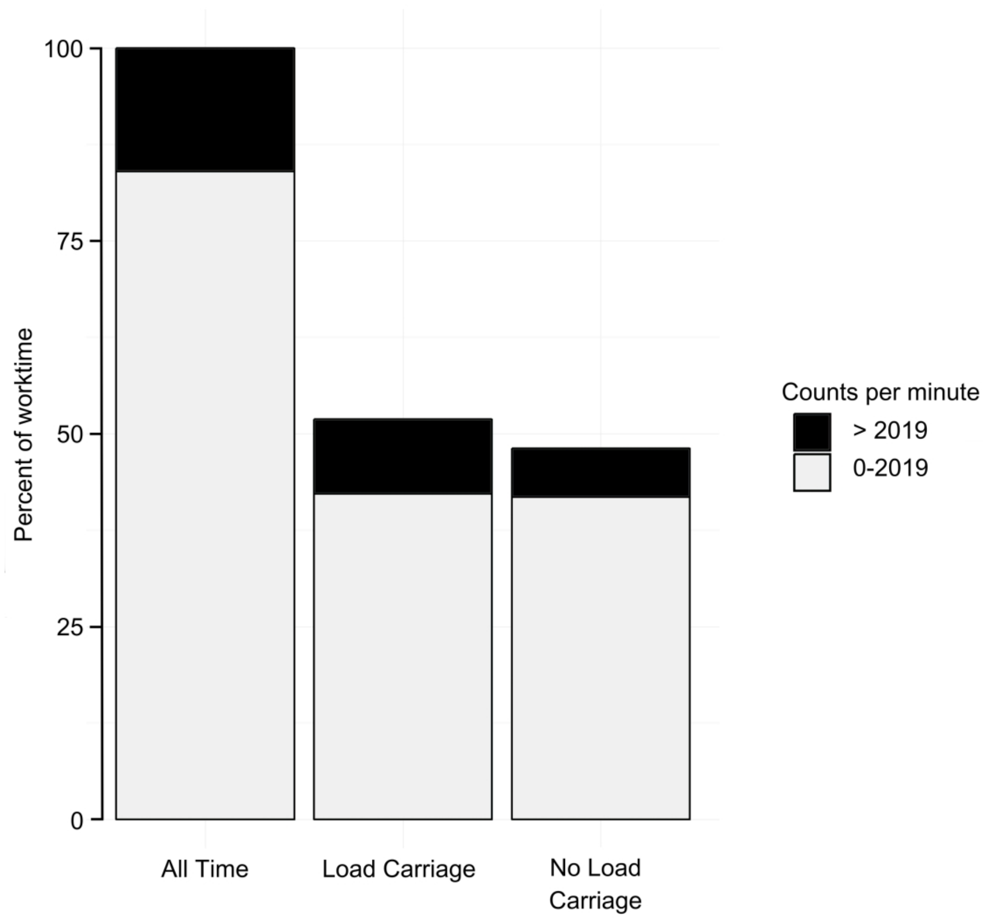

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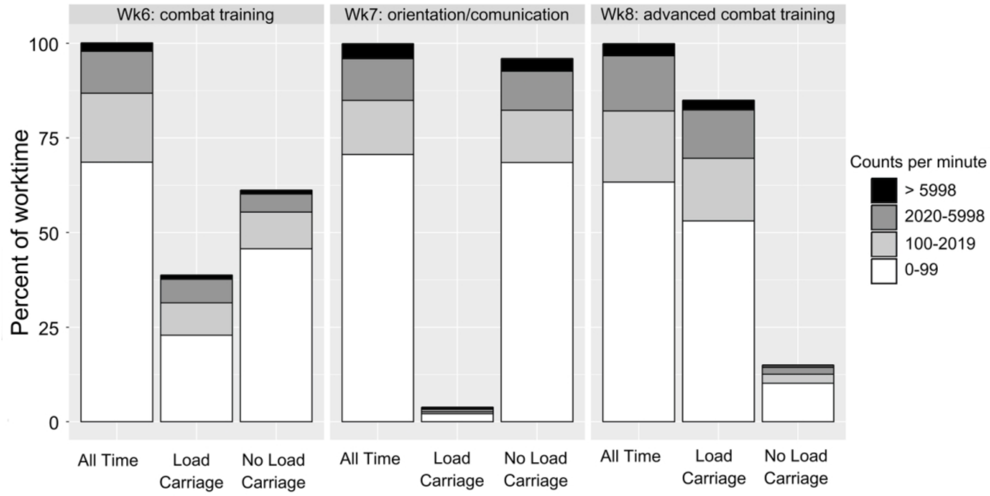

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65x33mm (600 x 600 DPI)

A longitudinal observational study of back pain incidence, risk factors, and occupational physical activity in Swedish marine trainees

Supplementary Files

Supplementary Table 1. Incidence rate (IR) based on time to first LBP, and LBP limiting work-ability, episode during the marine training course.

	LBP			**LBP limiting work ability**		
	Time at risk	**IR**	**95%CI**	**Time at risk**	**IR**	**95%CI**
Per 100 person-weeks	398 person weeks	9.0	6.5-12.5	539 person weeks	3.9	2.5-6.0
Per 1000 person-days	2786 person days	12.9	9.3-17.9	3773 person days	5.6	3.6-8.5

Supplementary Table 2. Regression analyses of individual physical characteristics, work- and health-related risk variables: initial multiple hazard ratio (HR) for low back pain (LBP) and LBP limiting work ability during the marine training course.

Variable	LBP Initial Multivariable				LBP limiting work ability Initial Multivariable			
	HR	**95% CI**		**p value**	**HR**	**95% CI**		**p value**
Physical characteristics								
Body Height ≤1.80 (m)	1.69	1.02	2.79	0.040	2.90	1.31	6.43	0.009
Rated health/health history								
Back Pain; within 6 mo. prior to course start	1.61	0.85	3.05	0.145	2.42	0.89	6.55	0.082
Hip/Knee Pain; within 6 mo. prior to course start	1.30	0.75	2.27	0.350				
Neck/Shoulder Pain; within 6 mo. prior to course start	1.25	0.68	2.35	0.483	2.35	0.76	7.21	0.136
Work-related								
Current Work ability with regard to best ever	1.48	0.86	2.54	0.152				
Physical training habits past 6months								
Physical training;								
≤ 2 sessions/week					3.16	1.23	8.13	0.017
Muscular strength training;								
≤ 1 sessions/week					0.44	0.12	1.61	0.215
2-4 sessions/week								
≥ 5 sessions/week					1.27	0.45	3.54	0.649

Supplementary Table 3. Regression analyses of clinical tests: univariate and multiple final adjusted† hazard ratio (HR) for low back pain during the marine training course.

	Univariate				Final Adjusted Model[a]			
	HR	**95% CI**		**P value**	**HR**	**95% CI**		**P value**
Physical/clinical tests								
Kettlebell lifts; kg*rep								
≤760 (lowest tertile)	1.48	0.82	2.67	0.198				
Sensitivity analysis								
CC (i.e. only male)	*1.44*	*0.76*	*2.7*	*0.261*				
Imputed (only male)	*1.48*	*0.75*	*2.91*	*0.256*				
Pull-ups								
≤ 3	1.99	1.11	3.56	0.020	1.87	1.17	3.01	0.009
Sensitivity analysis								
CC (i.e. only male)	*2.00*	*1.10*	*3.66*	*0.025*	*1.82*	*1.16*	*2.88*	*0.009*
Imputed (only male)	*1.94*	*1.06*	*3.54*	*0.032*	*1.81*	*1.13*	*2.91*	*0.014*
MCM-Tests, direction specific;								
DLL-L Flex; *Fail*	0.82	0.39	1.75	0.613				
DLL-L Ext; *Fail*	0.82	0.47	1.46	0.508				
DLL-ALE Flex; *Fail*	0.71	0.32	1.56	0.388				
DLL-ALE Ext; *Fail*	1.35	0.76	2.40	0.310				

[a]Adjusted for prior back pain and body height

Abbreviations; CC; complete cases, DLL-L Flex; Double leg lift-lower lumbar flexion-control, DLL-L Ext; Double leg lift-lower lumbar extension-control, DLL-ALE Flex; Double leg lift-alternate leg extension lumbar flexion-control, DLL-L Ext; Double leg lift-alternate leg extension lumbar extension-control.

Supplementary Table 4. Regression analyses of clinical tests: univariate hazard ratio (HR) for low back pain limiting work ability during the marine training course.

	HR	95% CI		P value
Physical/clinical tests				
Kettlebell lifts; kg*rep				
≤*760 (*lowest tertile)	1.02	0.67	1.54	0.923
Sensitivity analysis				
Complete cases (i.e. only male)	*1.10*	*0.31*	*3.92*	*0.884*
Imputed (only male)	*1.12*	*0.37*	*3.39*	*0.834*
Pull-ups				
≤ 3	1.02	0.75	1.38	0.912
Sensitivity analysis				
Complete cases (i.e. only male)	*1.23*	*0.42*	*3.64*	*0.709*
Imputed (only male)	*1.29*	*0.46*	*3.60*	*0.631*
MCM-Tests, direction specific;				
DLL-L Flex; *Fail*	0.71	0.21	2.43	0.587
DLL-L Ext; *Fail*	0.85	0.35	2.06	0.715
DLL-ALE Flex; *Fail*	0.76	0.23	2.54	0.650
DLL-ALE Ext; *Fail*	0.71	0.29	1.73	0.452

Abbreviations; DLL-L Flex; Double leg lift-lower lumbar flexion-control, DLL-L Ext; Double leg lift-lower lumbar extension-control, DLL-ALE Flex; Double leg lift-alternate leg extension lumbar flexion-control, DLL-L Ext; Double leg lift-alternate leg extension lumbar extension-control.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page 1 and 2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 4
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 4-5
Methods			
Study design	4	Present key elements of study design early in the paper	Page 5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 5 and Fig.1
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	Page 5 and 13
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Pages 13-14 and Table 1-2
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Table 1-2
Bias	9	Describe any efforts to address potential sources of bias	Page 14-16
Study size	10	Explain how the study size was arrived at	Page 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Table 1-2
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 14-16
		(*b*) Describe any methods used to examine subgroups and interactions	Page 15-16
		(*c*) Explain how missing data were addressed	Page 14
		(*d*) If applicable, explain how loss to follow-up was addressed	Pages 13-14 and Fig.1
		(*e*) Describe any sensitivity analyses	Page 14

Results			Page 16
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Page 5, Fig 1. and Fig.3
		(b) Give reasons for non-participation at each stage	Page 5, Fig 1. and Fig.3
		(c) Consider use of a flow diagram	Fig 1.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Page 5 and table 3
		(b) Indicate number of participants with missing data for each variable of interest	Page 14
		(c) Summarise follow-up time (eg, average and total amount)	Supplementary Table 1.
Outcome data	15*	Report numbers of outcome events or summary measures over time	Page 16-17, Fig. 2-3 and Supplementary Table 1.
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 16-17, Table 4-5 and Supplementary Table 3-4.
		(*b*) Report category boundaries when continuous variables were categorized	Tables 1 and 2
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Page 16-21, Supplementary Table 2-4.
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 21
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Pages 21-24
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 21-22
Other information			

Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 25

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.