Chapter #14

WELLBEING OF MILITARY PERSONNEL AS REFLECTED IN SLEEP QUALITY

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ABSTRACT
Military service is both physically and mentally demanding, so the purpose of this text is to find the best selection of methods that can describe the wellbeing of soldiers. In this study, we chose two specific military groups that have very different tasks in the Czech Army to determine their actual physical and mental states. The first group was the military Castle Guard, and the second group was military paratroopers. Both of these groups underwent psychological testing of personality, IQ, self-evaluation, cognitive abilities, and the motivation to perform the duties of military service. Physical health was tested by a body composition analysis, health-related biochemical parameters, sleep analysis, and diagnostics on the musculoskeletal apparatus. Our study aimed to find significant associations that have an impact on the wellbeing of elite Czech military units, and for this purpose, we used the association rule learning method. The results of this study demonstrate that the most significant associations were found between wellbeing reflected in life satisfaction and the health condition of soldiers and their quality of sleep.

Keywords: military personnel, wellbeing, combat readiness, sleep analysis.

1. INTRODUCTION

Military personnel are daily confronted with mental and physiological challenges given by a difficult working environment defined by its rules, responsibilities, and discipline. To perform well under these conditions, it is necessary to consider both mental and physical wellbeing within a single context (Hernández-Varas, Encinas, & Suárez, 2019). This study aims to reveal the current state of the Czech Army in the very different, but both highly responsible, aspects and to see which components play the main role in their wellbeing. Since the Czech Army is fully professional and it's more and more difficult to find competent personnel, it is important to help current soldiers keep fit. This broad-spectrum study was prepared to find the most useful methods to detect the mental and physical states of soldiers, which is subsequently reflected in their rate of injuries, chronic pain, and lowered motivation. The purpose is to find the most significant connections between life and work satisfaction and the current state of cognitive functions, sleep quality, and health conditions. These connections are not necessarily limited to the work environment, but they extend to the domestic environment as well. This chapter is an extension of a previously published article (Kloudova, Gerla, Rusnakova, Belobradek, & Stehlik, 2020).

2. BACKGROUND

This broad-spectrum study was designed to verify the mental and physical wellbeing of military units. Since the ways of measuring wellbeing are numerous, it is vital to establish the effective conceptualization and the clarity of what is meant to be measured (Fisher, 2014). Wellbeing is usually perceived through judgments made by the individual himself. But beyond those generalities, the phenomenon has many forms, and it might be helpful to incorporate some objective methods as well. Military personnel are usually tested regarding their work stress rather than their non-occupational issues, many of which play a crucial role in a person's wellbeing (Sanchez, Bray, Vincus, & Bann, 2004). This study might be perceived as job satisfaction research, which is usually limited to the job itself. However, wellbeing is also reflected in the time spent outside work and overall satisfaction with personal life, including its time management, relaxation, appearance, and relationships, that might influence life vitality and professional performance. Soldiers regularly undergo psychological testing, which is utilized in describing, explaining, predicting, and modifying behaviors (Nwafor & Adesuwa, 2014). However, to prevent possible problems, it is necessary to include testing for motivation, cognitive ability, self-evaluation, and IQ, as well to keep performance at the highest level. A high motivation to work in the military and a dedication to the cause can help protect against posttraumatic stress disorder (PTSD) together with better intellectual functioning (Kaplan et al., 2002). Good cognitive abilities are usually a decisive factor in a soldier's tasks, and they should be kept at the highest possible level. Findings indicate that when soldiers are under stress their decision-making and cognitive functioning are significantly decreased, which can also result in lowered shooting accuracy (Nibbeling, Oudejans, Ubink, & Daanen, 2014).

There is evidence that poor sleep, as seen in insomnia, may cause cognitive impairments (Fulda & Schulz, 2001). Moreover, poor sleep can be associated with additional health concerns, less physical activity, less vitality, and more emotional problems (Zammit, Weiner, Damato, Sillup, & McMillan, 1999). Even one night of sleep deprivation can cause considerable deterioration in alertness and performance, which makes accidents in the workplace more likely (Van Dongen, 2006). Good and poor sleepers differ in working memory, fluid intelligence, and the shifting of their attentional set (Buysse, 2014), which has a big influence on combat performance. Studies show that the quality of sleep is affected by occupation, and there is a significant association between the quality of life in military forces and their sleep patterns (Roustaei, Jamali, Jamali, Nourshargh, & Jamali, 2017). Especially in the military environment, sleep can be impaired because of common shift changes. Night-shift soldiers have significantly worse sleep efficiency as compared to day-shift soldiers. They also reported more problems falling asleep and staying asleep compared to the day-shift (Peterson, Goodie, Satterfield, & Brim, 2008). Disrupted sleep, as is usually seen in military personnel on duty, results in a high risk of daytime sleepiness and fatigue (Toblin et al., 2012). A sleep deficit decreases combat performance, and there is a significant association between the number of hours of sleep and the incidence of mistakes and potential accidents (LoPresti et al., 2016). Sleep is essential for normal brain functioning and emotion regulation. Its loss can lead to mood changes, cognitive impairment, and abnormal hormonal rhythms (Wilson & Nutt, 2008). Unfortunately, among the military, little attention is paid to sleep quality. When taking breaks, the rest areas for soldiers are not optimized for healthy sleep, as sleeping areas are usually uncomfortable and noisy (Troxel et al., 2015). The same situation was described by the soldiers tested in our study, and it is true for the Czech Army overall. Sleep is currently disregarded during operational planning, although it might produce significant advantages in increased readiness and resilience (Mysliwiec, Walter, Collen,

& Wesensten, 2016). In operational planning, the breaks and spare time are not well-organized, so, instead of sleeping, soldiers communicate with their families or play video games (Pruiksma & Peterson, 2018). Too much excitement before sleep produces insomnia among military personnel (Bonnet & Arand, 2010; Ramos, Arvelo, & Gomez, 2013).

The biochemical parameters related to stress and overload are usually cortisol, creatine kinase (CK), and urea. Fatigue is most accurately reflected in urea for endurance activity. On the other hand, for strength training, the best blood-borne marker reflecting fatigue is increased CK (Hecksteden et al., 2016). Creatine kinase is an enzyme that catalyzes the conversion of creatine to creatine phosphate, which serves as energy storage in the body. Serum CK increases in healthy participants right after exercise which consists of a very intense muscular load, and it is probably the best biochemical marker of muscle fiber damage (Mougios, 2019). Urea is formed in the liver, and it is the end product of protein metabolism - amino acid degradation. In the body, it serves as the main product of the excretion of excess nitrogen from the body. After performing a long-lasting exercise, there is usually a higher concentration of urea present in the blood (Viru & Viru, 2001). The accumulation of urea does not change during short-term exercise, but it increases with longer-lasting effort and depends primarily on the duration and intensity of exercise (Mougios, 2019). Cortisol is known to be a key factor in the biological stress response, and it mainly contributes to the regulation of stress responses (Glienke & Piefke, 2017). An increased release of cortisol occurs in a body facing a stressor by up to ten times the normal amount (Lüllmann, Mohr, & Wehling, 2004). Measuring cortisol at rest can help estimate physical and mental stress, while measuring cortisol after exercise can show the adaptation of the body to a certain stress load level (Mougios, 2019). Exercise based on endurance can cause significant changes in resting cortisol values (Anderson, Lane, & Hackney, 2016). Stress also significantly affects the quality of sleep, which can be reflected in cortisol secretion. Cortisol secretion is suppressed in sleep, and therefore during sleep deprivation the level of night cortisol increases slightly. In long-term sleep deprivation, the cortisol level tends to remain higher and can be a marker of chronic insomnia (Basta, Chrousos, Vela-Bueno, & Vgontzas, 2007).

While a number of test batteries and procedures are used in the military to determine physical fitness, muscle strength, and endurance, unfortunately, they are often not sufficiently relevant or reliable to predict an increased risk of injury or to assess real physical performance (Malmberg, 2011; Larsson, Tegern, & Harms-Ringdahl, 2012). Due to the discrepancy between the requirements for military personnel and their actual physical abilities, a risk of chronic disability may occur (Larsson et al., 2012; Payne & Harvey, 2010). The test of muscle imbalance could be a good indicator of possible future problems. This is because the number of individuals with muscle imbalance has increased. Muscle imbalance especially occurs in the lower limbs, which are usually caused by incorrect posture or inappropriate lifestyle (Kang et al., 2011). Many sports facilities, including those in the military environment, are more focused on the upper limbs, which can also cause muscle imbalance (Kang et al., 2011). If the muscular imbalance is in the range of 10% of muscle strength, it increases the frequency of injuries in athletes (Askling, Karlsson, & Thorstensson, 2003).

3. PARTICIPANTS

The participants tested were from two military groups significantly different in their types of duty. The first group consisted of 105 men working as the Castle Guard, ensuring the protection of the Czech president and other statesmen. The second group consisted of 101 men working as paratroopers (military parachutists) in the Czech Army. Their duty is quite

different in physical demands and also in keeping a different sleep schedule. The airborne group gets a full night's sleep, even when on duty, but the Castle Guard group sleeps in 2-hour intervals. The schedule is divided into a 2-hour duty, a 2-hour rest, and 2-hour preparation for the next duty, including night shifts. On the other hand, the airborne group has much more strenuous physical demands, and there is a greater risk of injuries.

4. METHODS

To analyze sleep and its impact on the performance of soldiers on duty, we used **actigraphy** to extract the main actigraphic variables. For this purpose, we used a Mindpax MindG bracelet actigraphic device, which is a battery-powered unit with a Kionix KX022 accelerometer. Detailed indexes derived from actigraphic data include: average sleep time per 24-hour period, time to fall asleep, wake-up time, number of arousals during sleep, sleep efficiency estimate, amount of daily sleep, amount of daily activity, chronotype estimate, percentage and stability estimates of individual sleep stages (deep sleep, light sleep, REM), the regularity of wake-up time, speed of falling asleep, etc. These indexes were computed as a mean value over multiple days (2-14 days for individual participants). AKTI_IND features were transferred to a 5-point scale, where 1 is the minimum, 2-3 is average for the given population, and 5 is the maximum.

The body composition measurement device was a Tanita foot-to-foot and hand-to-foot bioelectrical impedance analyzer. The MC780U Multi Frequency Segmental Body Composition Analyzer was used in this study and provided data on weight, body fat, fat mass, muscle mass, total body water, body mass index, bone mass, and basal metabolic rate.

Biochemistry data were obtained by a biochemical analysis from a blood sample. For all participants, a capillary blood sample was taken and immediately analyzed using a dry chemistry method (SPOTCHEMTM EZ SP-4430). Further, hormone cortisol was measured in the blood sample by the enzyme-linked immunosorbent assay (ELISA).

The muscle endurance test was based on the McGill test (McGill, Childs, & Liebenson, 1999) protocols divided into four core endurance tests. The participants were instructed to hold a static position for as long as possible. The endurance tests included the trunk flexor test, the trunk extensor test, and the bilateral side bridge test.

Cognitive tests were administered to measure the level of the cognitive performance of the soldiers. The test battery contained the psychomotor vigilance test (PVT), Go/NoGo, visual search, inhibition of return, the Corsi block test, and the Mackworth clock task. The tasks assigned are described in more detail in the PsyToolkit SW (Stoet 2010; Stoet 2017).

Psychological data were obtained by the NEO-PI-R personality test which can detect the main tendencies for neuroticism, depression, conscientiousness, and agreeableness (Costa & McCrae, 2008). The motivation to work in the military and to perform daily duties was measured by a series of questions covering the weekly schedule of the soldiers, including work, family, and leisure balance, and their motivation to make any changes. Another method was mapping the life satisfaction of the soldiers tested using a self-evaluation questionnaire based on life satisfaction scales (Fahrenberg, Myrtek, Schumacher, & Brahler, 2001) adapted and shortened for the military environment. The task was to evaluate each item on a scale of 1-10 from worst to best. The test had 10 scales referring to appearance, health, independence, physical fitness, work success rate, sexual performance, ability to satisfy one's partner, vitality, and life satisfaction. The IQ test used was the Efekt computer-based test, which along with the usual IQ score provided data about the level of aspiration of the participants tested based on Kurt Lewin's research (Lewin, Dembo, Festinger, & Sears, 1944). Strategy feature tells us how accurately the person evaluates his abilities. The points awarded are based on the level of another question the participant chooses after failure or correctly answered question. So, the higher the number of points is the higher aspirations the person has, and the

person takes more risks. The Cata feature in the Efekt test means that, even after a correct answer, the person lowers his aspirations and chooses an easier question. The Pole feature is about overestimating abilities, because the person chooses a more difficult question after a failure. So, the lower the number of points is the greater the level of aspirations the person has.

All of the last three mentioned tests were specially constructed by CASRI (Sport Research Institute of Czech Armed Forces) for this research project, although their significance among military personnel has already been proven in previous projects conducted by the Czech Armed Forces.

5. RESULTS

5.1. Feature extraction and selection

The first step to define the results was feature extraction and selection. In this study, we obtained a total of 149 features (see Table 1). We do not describe all the features in detail due to the high number of features and their nature.

Table 1.

List of extracted features. The table provides a brief overview of all 149 features. The most important features are discussed in more detail in the Results section. The last column shows the color for each group.

Group name and acronym	Number of features	Short description	Color
Actigraphy AKTI	63	Detailed indexes derived from actigraphic data: average sleep time per 24-hour period, time to fall asleep, wake-up time, number of arousals during sleep, sleep efficiency estimate, amount of daily sleep, amount of daily activity, chronotype estimate, percentage and stability estimates of individual sleep stages (deep sleep, light sleep, REM), the regularity of wake-up time, speed of falling asleep, etc. These indexes were computed as a mean value over multiple days (2-14 days for individual participants) and are marked as AKTI_RAW. AKTI_IND features were transferred to a 5-point scale, where 1 is the minimum, 2-3 is average for a given population, and 5 is the maximum.	(blue)
Health condition BIO	58	Highly detailed anthropometry information (age, height, and 21 other body composition measurement values obtained from Tanita), number of years in the army, a muscle endurance test for each limb, biochemistry data (UREA, CK – creatine kinase, cortisol).	(red)
Cognitive tests KOGNI	7	Final scores for 6 cognitive tests and summary mean score over all 6 tests.	(orange)
Psychological data PSYCHO	21	Subjective data from the questionnaires was used: NEO-PI-R personality test, work motivation, self-evaluation, IQ, and aspiration level tests.	(green)

In this study, we worked with incomplete data, because it was not possible to perform all the necessary experiments on all the participants analyzed. The final missing data rate is shown in Figure 1. Features whose missing data rate was above the threshold *th = 75%* for at least one dataset were removed and not considered in further analyses. The total number of features after feature rejection was 118.

Figure 1.
Missing data rate for both datasets over all 149 features.
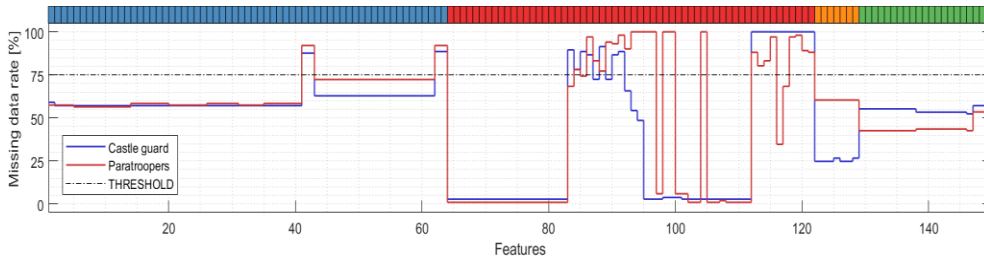
5.1.1. Association rules learning

We used association rules-based machine learning to discover interesting relationships hidden in both datasets. Association rules allow us to identify more complex dependencies that could not be detected by a simple algorithm, such as correlation analysis. An apriori-type algorithm for generating the association rules executed in the Weka software was applied (Frank, Hall & Witten, 2016). The algorithm iteratively reduces the minimum support until it finds the required number of rules with the given minimum confidence. Confidence (conf: in Tables 2 and 3) is computed as the proportion of the examples covered by the premise that is also covered by the consequence. We used a "lift" metric with the minimum of criteria set to 1.1. Lift is confidence divided by the proportion of all examples that are covered by the consequence. This is a measure of the importance of the association that is independent of support. The description of the data showed in Tables 2 and 3 regarding results are explained in Table 1 and in the Methods section.

As typical for association rule learning, the number of rules found was enormous. The total number of association rules found for the Castle Guard group was 757,599 and for the paratrooper group 307,304. The most relevant results are based on counting only simple rules across different groups with a lift >2. The number of rules found for the Castle Guard group was 190 and for paratrooper group was 20. In Table 2 and Table 3, the most significant results for each group regarding the lift parameter can be found. This is a direct output of the Weka software (Frank et al., 2016).

Table 2.
Best rules found for the Castle Guard dataset.

Real wake time Number of participants
⇑ ⇑

1.	AKTI_RAW___Median_wake_time_h="(7.32-9.08]" 17 ==> PSYCHO___Self-evaluation___Vitality="(7.9-8.6]" 11 conf:(0.65) **< lift:(4.53)>**
2.	PSYCHO___Self-evaluation_Vitality="(7.9-8.6]" 15 ==> AKTI_IND___Continuity_of_sleep_estimated_by_number_of_microarousals="(2.6-3]" 12 conf:(0.8) **< lift:(3.65)>**
3.	AKTI_IND___Continuity_of_sleep_estimated_by_height_of_microarousals="(2.6-3]" 23 ==> PSYCHO___Self-evaluation___Independence="(9.5-inf)" 11 conf:(0.48) **< lift:(3.59)>**
4.	AKTI_IND___Sleep_efficiency="(2.6-3]" 23 ==> PSYCHO___Self-evaluation_Appearance="(6.8-7.2]" 11 conf:(0.48) **< lift:(3.59)>**
5.	PSYCHO___Self-evaluation_Health="(8.5-9]" 16 ==> AKTI_IND___Average_number_of_arousals="(2.6-3]" 12 conf:(0.75) **< lift:(3.42)>**
6.	PSYCHO___Self-evaluation_Ability_to_satisfy_partner="(7.9-8.6]" 17 ==> AKTI_IND___Average_time_to_fall_asleep="(2.8-3]" 12 conf:(0.71) **< lift:(2.96)>**
7.	AKTI_IND___Average_time_to_fall_asleep="(2.8-3]" 25 ==> PSYCHO___Efekt___Strategy="(380.9-422.8]" 12 conf:(0.48) **< lift:(2.8)>**
8.	AKTI_RAW___Average_time_of_awakening="(5.8-7.75]" 28 ==> PSYCHO___Self-evaluation__work_success_rate="(7.6-8.4]" 11 conf:(0.39) **< lift:(2.58)>**
9.	AKTI_RAW___Daytime_sleep__in_hours="(1.94-2.86]" 13 ==> PSYCHO___Efekt___Cata="(-inf-0.3]" 11 conf:(0.85) **< lift:(2.47)>**
10.	PSYCHO___Efekt___Cata="(-inf-0.3]" 36 ==> AKTI_IND___Estimated_time_spent__in_a_deep_sleep="(2.6-3]" 18 conf:(0.5) **< lift:(2.28)>**

Self-evaluated vitality has the most significant association with median wake time (lift:4.53) and continuity of sleep (lift:3.65). The longer the subject sleeps and the more continuous sleep the subject gets, the greater the life vitality the subject perceives. There are more sleep-relevant features, like the continuity of sleep and self-perceived independence (lift:3.59), sleep efficiency and appearance (lift:3.59), and the lower number of arousals during sleep which are reflected in self-evaluated health (lift:3.42). Also, the self-evaluation of the ability to satisfy one's partner is mostly related to the average time to fall asleep (lift:2.96). The participants that fall asleep more regularly feel more capable of satisfying their partner. The average time to fall asleep is also related to the level of accurate aspirations from the Efekt test, as shown by the Strategy feature (lift:2.8). A more regular time of awakening is related to the self-perceived work success rate (lift:2.58). More daytime sleeping lowers participants' aspiration, as reflected in the Cata feature together with a lower time spent in a deep sleep (lift:2.28).

Table 3.
Best rules found for the paratroopers' dataset.

1.	KOGNI___CORSI="(40-50]" 13 ==> PSYCHO___Self-evaluation___work_success_rate="(7.9-8.6]" 10 conf:(0.77) **< lift:(2.99)>**
2.	AKTI_RAW___Dispersion_of_sleep_effectivity_% ="(1.3-1.95]" 14 ==> Self-evaluation_work_rate_success="(7.9-8.6]" 10 conf:(0.71) **< lift:(2.77)>**
3.	AKTI_RAW___Number_of_awakenings_per_hour_>_10_min="(-inf-0.04]" 23 ==> BIO___Anthropometry___Basal_metabolism_kcal="(2097.5-2225.4]" 10 conf:(0.43) < **lift:(2.31)**>
4.	BIO___Anthropometry___total_body_water_kg="(50.75-53.62]" 20 ==> AKTI_RAW___Number_of_awakenings_per_night_>_10_min="(-inf-0.45]" 11 conf:(0.55) < **lift:(2.22)**>
5.	AKTI_IND___Average_length_of_sleep="(-inf-3.1]" 21 ==> PSYCHO___Self-evaluation___Independence="(8.6-9.3]" 11 conf:(0.52) **< lift:(2.2)>**
6.	BIO___Anthropometry___Body_weight_kg="(69.35-80.84]" 32 ==> PSYCHO___Motivation_to work="(-inf-0.26]" 11 conf:(0.34) **< lift:(1.93)>**
7.	AKTI_RAW___Average_time_to_fall_asleep="(21.52-inf)" 32 ==> PSYCHO___SAT___Neuroticism="(497.6-541.62]" 11 conf:(0.34) **< lift:(1.83)>**
8.	BIO___Biochemistry___CK="(-inf-4.32]" 47 ==> PSYCHO___Self-evaluation___Work__success_rate="(6.5-7.2]" 11 conf:(0.23) **< lift:(1.82)>**
9.	AKTI_IND___Sleep_efficiency="(2.6-3]" 16 ==> PSYCHO___Efekt___Pole="(-inf-455.5]" 12 conf:(0.75) **< lift:(1.8)>**
10.	AKTI_RAW___Dispersion_of_night_sleeping_time_in_hours="(0.87-1.16]" 15 ==> BIO___Anthropometry___Body_weight_kg="(80.84-92.33]" 11 conf:(0.73) **< lift:(1.76)>**

The most significant association in the paratroopers´ dataset was found between the score in cognitive testing (KOGNI_CORSI) and self-evaluated work success rate (lift:2.99). These results seem accurate, since the paratroopers need to concentrate and have precise and effective decision making. Professional success is also related to a low level of dispersion of sleep efficiency (lift:2.77), which means that the person usually gets the same effective sleep over the 14-day measurement period. Other significant biological associations were found, such as a low percentage of awakenings and higher basal metabolism (lift:2.31) together with higher total body water (lift:2.22). The more continuous sleep the person gets the better basal

metabolism the person has, together with a healthier water ratio in the body. Lower length of sleep is related to a lower self-evaluation of independence (lift:2.2). Motivation to work is lowered by increasing body weight (lift:1.93). Longer average time to fall asleep points to increasing neuroticism, as measured by a personality test (lift:1.83). The work success rate was reflected in biochemical features such as CK (creatine kinase). It reflects fatigue and muscle fiber damage, which usually occurs after intense endurance training. The lower CK that was present in the blood the lower the self-perceived work success rate that soldiers mentioned (lift:1.82). If the sleep efficiency is within the average range, the more accurate aspirations the subject had regarding the Pole feature in the Efekt test (lift:1.8). Increased body weight can be also reflected by the dispersion of night sleeping time in hours (lift:1.76).

6. CONCLUSION/DISCUSSION

The purpose of this study was to examine the most useful methods and feature extraction algorithms that effectively reflect the physical and mental health of the Czech Armed Forces. Since the workload and work schedule can vary among military units, we chose two specific units that have very different duties and organizational planning. In the Results section, only the 10 most significant associations based on lift parameters were chosen. The differences between these units can be seen in the results, where the features for the Castle Guard group were mostly related to sleep quality. The paratrooper unit had slightly different results more closely related to biological markers, although sleep plays a role in their health and work success as well. The health condition is reflected more in the work success of the paratroopers than the Castle Guard group, since their job is mostly physically demanding and without optimal body weight and fitness, they are not able to perform.

The results indicate that self-perceived vitality, work success, and health condition are mostly reflected by sleep-related features. Given the analysis of the 118 features extracted from various fields and commonly used methods to determine military personnel vitality (fatigue, work success, and overload), the sleep-related features demonstrated the most relevant associations.

To make conclusions for the military environment as a whole, it is necessary to differentiate between units, their work schedules, and their mental and physical demands. So, we cannot expect these results to be applied uniformly to all military personnel, which represents a substantial limitation. Also, a limitation of this study is the research sample, since it wasn´t possible to follow all of the 215 soldiers in total, due to their work assignment changes over the two years of the research. Some of the results are based on less than 20 participants, which implies they are not statistically significant.

Still, our results indicate a clear need for discussing and ensuring better sleep hygiene practices, which are often routinely disregarded during operational planning.

Giving these findings, the goal of new research might consider potential ways to measure various military units. Future possibilities can be also found in the proper education of the soldiers. Doing so, they would be able to follow the guidelines of a healthy lifestyle in their spare time to maintain mental and physical fitness and to improve operational longevity and combat performance. The implications of the study findings for applied psychology lie within a wider range of testing wellbeing. Defined as such, wellbeing is a very comprehensive construct, based not only on psychological but also on physiological features, including sleep and health-related parameters.

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