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TNO report

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Physical Demands, Mental Performance and Food Components in Military Settings

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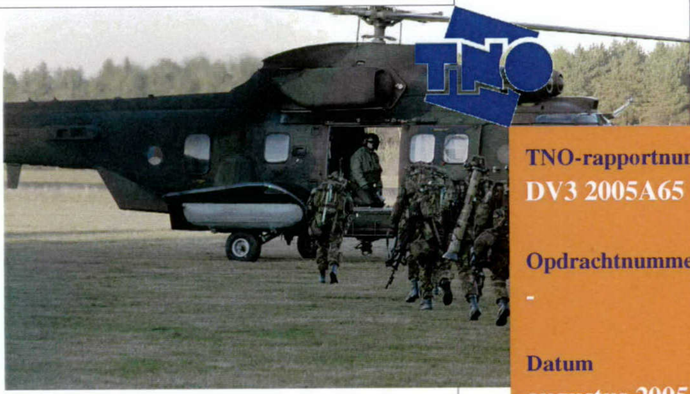
Fysieke eisen, mentale prestatie en voedingscomponenten in militaire settings



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Probleemstelling

Naar de relatie tussen fysieke eisen, mentale prestatie en voedingscomponenten is en wordt nog steeds veel onderzoek gedaan. Voor Defensie is het van belang dat deze relatie vooral in het licht van militaire settings wordt onderzocht. Sinds kort worden pogingen ondernomen deze settings in zogenaamde scenario's te beschrijven. Echter, om de effecten van een interventie, zoals die met voedingscomponenten, te kunnen bepalen, is het noodzakelijk dat standaard testprotocollen worden opgesteld. In opdracht van het Ministerie van Defensie heeft TNO Defensie en Veiligheid, locatie Soesterberg uitgezocht wat de randvoorwaarden zijn voor dergelijke protocollen en hoe deze in de toekomst dienen te worden uitgewerkt.

Beschrijving van de werkzaamheden

Op basis van literatuuronderzoek is vastgesteld welke factoren de relatie tussen fysieke inspanning en mentaal functioneren het sterkst bepalen. Vervolgens zijn op basis van fysieke, mentale en operationele eisen realistische scenario's geselecteerd en beschreven. Met het oog op deze eisen is een 'core'- set aan cognitieve vaardigheden gedefinieerd op basis waarvan een aantal prestatietests is geselecteerd en nader uitgewerkt. Evaluatie hiervan en ontwikkeling van taakvalide testprotocollen dienen in een vervolgstudie plaats te vinden. Een vergelijkbaar traject is gevolgd voor de relatie tussen voedingscomponenten en cognitief functioneren. Er is een inventarisatie gemaakt van voedingscomponenten die een effect hebben op de mentale prestatie en er heeft een selectie plaatsgevonden van middelen die in een militaire setting kunnen worden toegepast.

Resultaten en conclusies

Het blijkt ondoenlijk om alle mogelijke factoren in de relatie fysiek en mentaal presteren te onderzoeken. Daarom zijn er keuzes gemaakt. Er wordt een onderzoeksdesign voorgesteld waarin lage (patrouille) en hoge (offensief/defensief) fysieke belasting gedurende korte (tot 2 uur) en langere tijd (8-10 uur) worden onderzocht. Cognitieve taken dienen zich vooral te richten op vigilantie, werkgeheugen, logisch redeneren, complexe informatieverwerking en psychomotoriek. Voedingscomponenten die voor interventiestudies in aanmerking komen zijn koolhydraten, cafeïne en α-lactalbumine.

Toepasbaarheid

Op basis van dit rapport dient een onderzoeksprotocol te worden geformuleerd om de sensitiviteit en de grootte van de effecten te bepalen t.a.v. de relatie tussen fysieke belasting en mentale prestatie in een militaire setting. Vervolgens dient een standaardprotocol te worden ontwikkeld voor interventiestudies, zoals onderzoek naar de effecten van voedingscomponenten.

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Summary

Purpose
The relationship between physical demands, cognitive functioning, and food components is still an interesting field for research. For the Dutch Defence Organization it is important that this relationship is investigated with a special focus on military settings. Recently, attempts have been made to describe these settings in so called scenarios. However, to determine the effects of an intervention, such as food components, it is necessary to design standard test protocols. This study emphasizes the limiting conditions for these protocols and how to elaborate them in future.

Method
Investigating the literature, factors were determined that play a significant role in the relationship between physical load and mental functioning. Next, realistic scenario's were selected and described, based on physical, psychological and operational demands. Using these demands a core-set of cognitive abilities was defined and performance tests were selected and further elaborated. A comparable trajectory was followed for the relationship between food components and cognitive functioning. An inventory was made consisting of food components having an effect on mental performance and a further selection was performed with respect to military settings.

Results
It appears unfeasible to investigate all possible factors considering the relationship between physical and mental performance. Selections were made and it is proposed to apply a 2 x 2 factorial design, incorporating physical load (low vs. high) and task duration (short vs. long). Cognitive tasks should aim at viligance, working memory, logical reasoning, complex information processing, and psychomotor behaviour. Food components that are considered for intervention studies are carbohydrates, caffeine, and α-lactalbumin.

Conclusion
Based on this report a research protocol should be designed to determine the sensitivity and magnitude of the effects with respect to the relationship between physical load and mental performance in a military setting. Next, a standardized protocol needs to be developed for intervention studies, such as the investigation of food components.

Contents

1 Preface

The project 'cognitive functioning of operators under extreme conditions' started as a project proposal by TNO Nutrition and Food Research (now TNO Quality of Life). The goal of the project was to unravel the relation of food components on cognitive functioning of soldiers.

Because the main focus was on cognition in terms of mental performance and information processing, TNO Human Factors (now TNO Defence, Security and Safety) was contacted to provide input on this topic.

In concert with the Defence project supervisor, the goal of the project was discussed and agreed upon (autumn 2004), the main aim being the description of the relationship between physical demands, mental processes and food components in military settings.

Due to the lack of information physical, mental and operational demands with respect to relevant military scenarios, more documentation was searched and consulted (report 'vignettes', NATO report and Koerhuis, 2004). Furthermore, the project supervisor was requested to provide scenario-related information.

Another meeting was arranged to address and discuss relevant scenarios based on the input of military experts (January 2005). As a result of this discussion the content of the report was further specified and the need for specific military input was expressed. Due to several reasons, this input appeared hard to get and therefore it was agreed that TNO would finalize the report.

The content of the report focuses on the identification of and the relationship between physical demands, mental processes and food components in different, relevant military tasks. Chapter 2 describes the background of this study report. Chapter 3 summarizes the relevant aspects with respect to the relationship between physical load and mental performance. Chapters 4 and 5 focus on military requirements in terms of realistic scenarios and the assessment of mental performance. Chapter 6 provides an overview of the different food components and their relationship with cognitive functioning. Finally, recommendations are given in chapter 7.

2 Background

The modern military soldier is confronted with physical demanding situations, changing task environments, and different information sources. As a consequence, soldiers not only have to be physically fit, but they also need to have the ability to take adequate and timely decisions, when they are or have been physically loaded. It is to be expected that physical load affects mental functioning in either a positive or negative way.

In order to select or develop mental performance tests to investigate the relationship with physical load, it is necessary to determine those fundamental aspects of the soldier that are relevant for his functioning. Furthermore, selected tests should show sufficient specificity and sensitivity.

If these requirements are adequately met, a protocol can be defined that enables researchers to investigate the effects of different stressors closely related to the working conditions (e.g. physical load profiles, clothing, climate, rapid deployment, working times, environment, etc.) and the positive effects of countermeasures (e.g. nutrition, climate control, alertness management, etc.).

3 Physical load and mental performance

From the literature it appears that the relationship between physical load and mental performance shows different profiles. Main factors influencing this relationship are:
- level and duration of the physical load;
- the mental performance test selected;
- physical fitness;
- experience and proficiency;
- age, and gender.

Studies addressing the effects of brief exercise on mental performance have shown that moderate physical activity improves cognitive performance while low or high activity do not. Improvements in performance induced by exercise are commonly associated with increase in arousal, while impairments are generally attributed to the effects of muscular or central fatigue (Devienne et al., 2001).
Hogervorst et al. (1996) investigated cognitive performance after strenuous physical exercise. They found an increase in cognitive performance speed after exercise. Experiments utilizing reaction time to measure the effects of fatigue on cognition must discern sensitivity of peripheral and central processing to strenuous exercise.
Fery et al. (1997) state that, if fatigue interacts with subjects' reaction time in a decision task, central processing is affected by fatigue. He showed that, using a memory task, decision reaction time was affected only during the exhausting bout of the progressive workload session and for the more difficult task.

No research was found addressing the effects of physical load during a prolonged period of physical rest. All the testing was done during or just after the exercise. If (mental) fatigue is an important factor, the effects of fatigue might be best demonstrated during a period some time after the physical exertion.

Both, physical and mental work, will lead to a state of a so called generalized fatigue. To assess the effects of this type of fatigue there does not exist 'the one and only test'. Therefore, researchers often describe specific abilities and capacities, such as vigilance, working memory, and complex information processing that are vulnerable when fatigue is a major issue of concern (Beaumont et al., 2003).

4 Military requirements

To develop protocols that will serve as guiding principles for the investigation of the effects of stressors and countermeasures on physical and mental performance, the following steps have to be taken:

1. Description of realistic scenarios for physical load profiles and mental performance requirements.
2. Selection of a set of mental performance tests, based on these scenarios.
3. Evaluation of this set of performance tests with respect to sensitivity and magnitude of the effects found, using the different physical load profiles.
4. Development of task-valid testing protocols.

Paragraphs 1 and 2 will be elaborated in this report, paragraphs 3 and 4 will be subject of investigation in a future study.

4.1 Description of realistic scenarios

The description of realistic scenarios with respect to physical load profiles is primarily based on the following documents:

- 'Tactisch optreden van kleine eenheden in vredesoperaties' (Smeenk et al., 2004).
- Physical demanding tasks and physical tests for a Dutch combat soldier (Koerhuis et al., 2004).

The Smeenk study (2004) lists the tasks of small units. The list and task descriptions were based on 6 missions conducted in the past (UNPROFOR, IFOR, SFOR, KFOR, ISAF, and UK golf). The study results show that the tasks 'observation posts', 'checkpoints' and 'patrols' are most frequently conducted by small units. Important tasks, but not performed frequently are 'Quick Reaction Force' and 'Showing the Force'. The study mainly deals with peace support operations and organizational aspects, since interaction with the local population, support organizations and former combatants is an important element of small unit tasks.

The study of Koerhuis et al. (2004) describes the assessment of physical performance addressing the most demanding tasks during different military scenarios. The findings of this study will be more elaborated in terms of physical, psychological, and operational demands.

4.1.1 *Physical demands*

The Koerhuis study (2004) evaluates demanding tasks during three different scenarios of combat soldiers: offensive, defensive, and peacetime scenarios. A distinction was made for 5 different groups: airmobile brigade, commandos, armoured infantry, marines and Object Ground Defence soldiers (OGRV-soldiers). The study provides a very useful schematic overview of the scenarios for the different groups (see for a summary, appendix A). Based on these figures, a selection can be made for the purpose of this study.

The results of the study indicate that the offensive and defensive scenarios are physically the most demanding ones. Within these scenarios loaded walking is the most demanding task for combat soldiers, bearing weights of more than 50 kg. Furthermore, ‘fire and manoeuvre’ activities, alternate kneeling and standing up, digging, lifting and carrying are mentioned.

The Dutch Army uses the so called FIT-test (Koninklijke Landmacht, 2003a) and a physical fitness test (Koninklijke Landmacht, 2003b) to assess the physical status of soldiers. Both tests have to be performed once a year, and it is assumed that they predict soldier performance in the field. The Koerhuis study (2004) does not mention any validation studies, but concludes that both tests could be improved by including more field related aspects.

4.1.2 Psychological demands

Although the scope of the Koerhuis study (2004) mainly is on physical load and demands, performance aspects of the tasks described can be used to produce a basic inventory of task related psychological or mental demands. The demands for combat soldiers depend largely upon the type of action to be required. In general terms, the following aspects are mentioned:
- observation, inspection and detection of threads;
- information gathering and decision making;
- aiming and firing;
- map reading;
- communication and coordination;
- stress and anxiety coping.

<u>Observation, inspection and detection of threads</u> highly depend on the soldier’s capability to remain vigilant. Impaired vigilance will lead to impaired perception of relevant signals, a prerequisite for this type of task.
<u>Information gathering and decision making</u> starts with the soldier’s capability to filter and select the right information. This selection will be based on the goals he wants to achieve and will be influenced by his experience. The next step will be the organization of information, using logical rules, so that he will be able to take a (right) decision. The complexity of the information and time stress will affect his performance.
<u>Aiming and firing</u> are strongly related to the soldier’s capability to concentrate, and to keep unintended body movements under control. Eye-hand coordination (perceptuo-motor skills) and the tremor-control are important factors affecting shooting performance.
<u>Map reading</u> is a typical task that needs concentration, and can be considered as a task that plays a role in the information gathering and decision-making process.
<u>Communication and coordination</u> as well as stress and anxiety coping are more general demands, are situationally determined, depend on experience, and are strongly related to personality characteristics.

4.1.3 Operational demands

Depending on the type of operation, combat soldiers have to act 24-48 hours without new provisioning. But for certain types of operation this period can last for 7-10 days (Commando groups).
Furthermore, in some occasions combat soldiers operate by night and sleep during the day, which means that detrimental effects of the disturbance of the circadian rhythm should be taken into account.
Environmental circumstances are another relevant issue combat soldiers have to deal with. Temperature (hot – cold) and altitude (mountainous terrain, aircraft jumping) are the most prominent environmental factors that affect operational performance.

4.2 Selection of mental performance tests

Performance measures used to assess psychological performance are many and varied. They generally include sensory, perceptual, cognitive, and psychomotor tasks in a single or multi task setting. Furthermore a distinction can be made between tasks that assess individual versus group performance.

When taking psychological and operational demands into account as described in section 4.1.2 and 4.1.3, at all events performance tests should address the following issues:

1 vigilance;
2 working memory;
3 logical reasoning;
4 complex mental performance;
5 psychomotor performance, steadiness and aiming.

4.2.1 *Vigilance*

Vigilance is a major element in many important military activities and tasks, such as sentry duty, watch keeping, vehicle operation, instrument monitoring, and surveillance. Analysis of vigilance behavior is a complex problem because it consists of several component behaviors such as attention, alertness, cognitive sensitivity, and judgment and decision making. Because of the role of vigilance in military activities, it is important to understand the effects of stressors such as physical load.

The Vigilance and Tracking task (Valk, 1994) assesses vigilance performance in terms of attention, alertness, and cognitive sensitivity. The task was identified as a sensitive task tapping vigilance performance during prolonged monotonous flight operations. The task is successfully applied in field studies concerning effects of fatigue and sleepiness in pilots (Valk & Simons, 1998; Simons & Valk, 1998; Valk, Simons, Goei, Van Hijum, 2003). Furthermore, this task was successfully applied in laboratory studies to demonstrate detrimental (residual) effects of alcohol, sedative effects of antihistamines as well as residual effects of hypnotics under conditions of simulated cabin pressure in a hypobaric chamber (e.g. Valk, Simons, Struyvenberg et al., 1997; Valk, Van Roon, Simons, Rikken, 2004). Recently, this task showed to be sensitive for the performance enhancing effects of modafinil and caffeine (Simons et al. 2004, in press).

4.2.2 *Working memory*

Memory function, and especially the working component, is often assessed by tasks like the Digit Memory Span Test (Baker et al., 1985) or adapted versions of this memory span task. Koelega (1995) discussed validity and sensitivity of this test with respect to alcohol and vigilance performance.

Another interesting memory functioning test is the Continuous Recall Test. This test is part of the so called Criterion Task Set (Shingledecker, 1984). Memory is continuously updated and retrieved. The test can be administered as a paced or a self-paced version. Compared to the Digit Memory Span Test, the distribution of scores on the different task parameters from the Continuous Recall Test is much more spread, which increases the sensitivity of this particular test.

4.2.3 *Logical reasoning*

Logical reasoning can be considered as an important element in the chain of information gathering, processing and decision making. Baddeley's Logical Reasoning Test (Baddeley, 1968) and adapted versions using the same algorithm are often used as a test tapping this capability. The test has proven to be sensitive for the effects of sleep deprivation and caffeine (Penetar et al., 1994; Ryman, Naitoh & Englund, 1985).

4.2.4 *Complex mental performance*

Complex tasks can roughly be divided into tasks addressing time-sharing and divided attention and more work related simulations and work sample tasks. Time-sharing and divided attention capabilities are mostly assessed by so called multiple performance tasks. The Multiple Task Performance Battery (MTPB, Chiles, Alluisi, & Adams, 1968) assesses monitoring, arithmetic, and complex code-solving performance in a time-sharing environment.

The MTPB served as a model for the later developed Multi-Attribute Task Battery (Comstock & Arnegard, 1992). The MAT battery provides a benchmark set of tasks for use in a wide range of laboratory studies of operator performance and workload. The MAT was developed by NASA / Langley Research Center (Arnegard, 1991; Comstock & Arnegard, 1992). The battery incorporates tasks analogous to activities that aircraft crewmembers perform in flight, while providing a high degree of experimenter control and performance data on each sub task. This test has proven to be sensitive for the detrimental effects of alcohol, and antihistamines (Meeuwsen et al., 1996; Valk, Simons, Struyvenberg et al., 1997; Valk, Van Roon, Simons, Rikken, 2004). Recently, the MAT also showed performance enhancing effects of modafinil and caffeine (Simons et al. 2004, in press).

4.2.5 *Psychomotor performance, steadiness and aiming*

Military operations require the performance of numerous tasks involving psychomotor components, such as object manipulation, manual dexterity, steadiness, aiming, and rifle marksmanship. In this respect a work sample test assessing aiming and shooting would be a valid tool to measure performance. Research has shown that simulator shooting tasks, such as the Noptel system (www.noptel.fi), have a high level of content validity and show sufficient sensitivity to detect detrimental effects of fatiguing exercise and positive effects of caffeine (Gillingham, Keefe & Tikuisis, 2004; Tharion, Shukitt-Hale & Lieberman, 2003).

5 Design and assessment measures

Considering the demands as described in chapter 4 of this report, it is not feasible to take into account all possible factors that play a role when investigating the effects of stressors and countermeasures with respect to physical and mental performance during military operations. Assumptions and selections have to be made. For practical reasons operational factors such as climate, altitude and sustained operations should not be considered in the first stage. Later on, the aggravating effects of cold and hot environments, operations at higher altitudes (>3.000 meters), and sustained operations lasting up to 72 hours can be investigated. At this stage, the main objective is to develop valid testing protocols that are based on sound relationships between physical load and mental performance. Furthermore, these protocols should have sufficient content validity; physical and mental task characteristics should be related to operational demands.

With respect to physical task aspects, it is suggested to consider a 2 x 2 factorial design, incorporating *physical load* (low vs. high) and *task duration* (short vs.long). Low physical load will be directly related to peace patrol and watch keeping activities. The main task during this condition will be (unloaded) walking. High physical load will be related to offensive and defensive activities. A set of standardized activities should be adapted to the needs of the testing protocol. Activities consist of short distance running, balance, lying/standing, crawling, stepping, climbing, and endurance. During these activities load can be varied. Task duration will be short (2 hours) or long (8-10 hours).

With respect to the assessment of mental performance the following tests are proposed:

Vigilance: Vigilance & Tracking test
The Vigilance and Tracking test (VigTrack) is a dual-task measuring vigilance performance under the continuous load of a compensatory tracking task. The task has been developed on a Psion 3a palmtop computer. The test is self-administered (no administrator on board) and needs circa 30 minutes practice time to eliminate significant learning effects (Valk et al., 1997). During the tracking task, subjects have to steer a cursor-block, using the arrow-keys, so that it is kept between two markers in the centre of the display. The cursor-block is programmed to move continuously from these two markers. While tracking, subjects have to perform the vigilance task. During this task a moving dot leaps between two horizontal lines on top of the computer screen. Most of the leaps are equidistant; however some of them are twice the normal size. If the latter is the case, subjects have to respond as quickly as possible by pressing a response button. The duration of this test can be set and performance measures included root mean square tracking error and percentage omissions.

Working Memory: Continuous Recall Test
The Continuous Recall Test (CRT) consists of digits (single, double or triple) that are presented simultaneously above and below a horizontal line on the computer screen. Subjects are required to memorize the digit(s) below the line, compare it with the digit above the line in the subsequent presentation, and respond by pressing the appropriate button for 'same' or 'different' number. The task is self-paced with a maximum reaction time of 2 seconds per response. The duration of this test can be set and response data and reaction times are recorded.

Logical Reasoning: Logical Reasoning Test
The Logical Reasoning Test (LRT) consists of sentence types involving different voice (active versus passive), use of negatives (not), and outcome (true versus false). Two probes are presented on the computer screen and below these probes a statement is made. Subjects have to look at the probes and decide whether the statement describing the order of the probes is correct or not (probes: AB; statement: A is followed by B; answer: correct). The test is self-paced and the duration can be set. Response data and reaction times are recorded.

Complex Mental Performance: Multi-Attribute Task battery
The Multi-Attribute Test battery (MAT) includes a system monitoring task, a tracking task, and a resource management task. Subjects have to perform these three tasks simultaneously during 10 minutes total test time. The system monitoring task, presented in the upper left window of the display, demands the subject to monitor gauges and warning lights. The subject responds to the absence of a green light, the presence of a red light, and monitors four moving pointer dials for deviation from midpoint. Monitoring performance measures include number of false reactions, number of omissions, and mean response time. The tracking task is located in the upper middle window. The target symbol is programmed to move continuously from the centre of the window. Using a trackball, the subject has to keep the target symbol in the centre of the window by compensatory tracking. Tracking performance is defined as the root mean square tracking error. The demands of fuel management are simulated by the resource management task, presented in the lower middle window. Subjects have to maintain the level of fuel in both tanks A and B at 2500 units each. In order to maintain this level, subjects must transfer fuel from the lower supply tanks by switching pumps 'on' and 'off'. The task is complicated by programmed pump failures. Resource management performance measures include the mean absolute deviation of fuel tanks A and B from the target of 2500 units. The MAT-battery will be performed on a personal computer.

Psychomotor performance, steadiness & aiming: Noptel Shooting Test
The Noptel Shooting Test uses a harmless light beam to measure the orientation path of the gun on the target. The system consists of a standard PC, an optical unit for the gun, a reflective target and the multi-user Windows software. The outdoor units are made to withstand military use and harsh environments. The main features of the Noptel system are its simplicity, fast installability and possibility for outdoor use on real ranges. Optical shooting systems haven proven their reliability and validity in several research projects (Tikuisis et al., 2002; Tharion et al., 2003).

6 Food components and cognitive functioning

6.1 Introduction

It is recognized that as part of an optimal military performance, rest capacity is needed to perform various cognitive tasks. In the previous chapters cognitive functioning and various mental factors were discussed for their applicability to improve the performance of the military tasks. The focus of this chapter is to identify food components that may help to improve cognitive functioning during these activities.
Based on two previous TNO reports (Voorrips and Dusseldorp, 2002; van Erp-Baart and Pasman, 2004) the following information is already available with respect to food components and cognitive functioning.

- Breakfast consumption is important for various cognitive functions, like short-term memory (especially auditive memory and textual memory).
- Glucose has a positive effect on reaction time, alertness and the speed of information processing.
- The amino acid taurine may, in combination with caffeine, have a positive effect on reaction time, mood, especially under sleep deprived conditions.
- Tryptophan, an essential amino acid, can increase serotonin levels in the brain and enhance positive mood (and reduce depression), although some negative side effects are known as well (like increased feelings of fatigue and increase in reaction time).
- Tyrosine, a non-essential amino acid, acts as a precursor of catecholamines, and could reduce the normal psycho-physiological effects of stress on cognitive function, resulting in better cognitive performance like pattern recognition and alertness.
- Choline, a part of the B-vitamins complex, can pass the blood-brain barrier. It has however not showed any effect on cognitive functioning yet. Therefore it is not advised as a potential enhancer of cognitive functioning.
- Supplementation of vitamin B1 might improve mood state and reaction time especially when the vitamin B1 level is low.
- Caffeine consumption may be positive for improving alertness and reaction time, especially in sleep-deprived subjects, as has repeatedly been found for physical effects in sports and military settings (Pasman et al., 1995; Graham, 2001; Bell and McLellan., 2003).
- Chocolate has a positive effect on mood because of its respected taste, not because of other mental benefits.
- Ginko Biloba seems to have a positive effect on various effects of cognitive functioning. The results are however inconsistent. It is therefore advised to further explore the effectiveness of this food component.

To update this inventory, an additional search was carried out to identify recent published documents on cognition in combination with physical exercise in military settings.

6.1.1 Carbohydrates

The importance of carbohydrates for cognitive functioning in relation to sustained, intense physical activities is explicitly mentioned by Lieberman (Lieberman et al., 2002). In an intervention study, Lieberman et al. investigated whether carbohydrate

administration improved vigilance during a day of sustained aerobic activity. It was concluded that supplementation of carbohydrate beverages enhanced vigilance and mood during sustained physical activity and interspersed rest. Subjects were 143 healthy men from the US Army, 2nd battalion. The test situation was carefully designed to simulate the physical demanding characteristics of a military mission and consisted of a 19.3 km march, a 30 minute rest, followed by a run of 4.8 km and after that they spend 4 hour in a heated tent.
It was concluded that subjects receiving carbohydrates reported significantly less confusion and significantly more vigor. There were no significant differences on other subscales of mood: tension-anxiety, depression-dejection, anger-hostility and fatigue-inertia.
The type of CHO that helps to improve cognitive functioning (feeling of fatigue) is further specified in a study of Pasman et al. (2003). It was demonstrated that consumption of a breakfast containing mainly complex carbohydrates resulted in less feelings of fatigue and increased satiety compared with a breakfast containing mainly simple carbohydrates.

6.1.2 *Protein*

Single amino acid supplements should not be used to modify cognitive performance, due to potential toxicity and sufficient evidence of inefficacy (Mil.Nutr.Board, 1999). Recently, Markus et al. (2005) reported that evening α-lactalbumin protein intake improved morning alertness and performance, especially in poor sleepers. This enhanced alertness is most likely a consequence of the improved sleep, as a result of the increased plasma tryptophan levels. This could also be interesting for soldiers on a mission, when sleep deprivation and shift-work affect the quality and quantity of sleep. For military settings, milk enriched with α-lactalbumin could therefore be an interesting topic for further investigation.

6.1.3 *Caffeine*

A report entitled: 'Caffeine for the maintenance of mental task performance: Formulations for military performance' has been prepared by the Board of Military Nutrition (Mil.Nutr.Board, 2001). In this report it is concluded that caffeine in doses of 100-600 mg may be used to maintain cognitive performance, particularly in situations of sleep deprivation.
Doses of 200-600 mg are assumed to be effective in enhancing physical endurance capacity. Furthermore, it may be useful in restoring some of the physical endurance lost in high altitude. It is advised to provide 100 mg doses, to allow individuals of smaller body size, non-habituated caffeine users, and those with an increased sensitivity to caffeine to use the product.
It is stressed that adequate food and fluid intake have to be monitored when caffeine is used for this purpose.

In a recent overview (Lieberman, 2003), the potential of caffeine, tryptophan and tyrosine for improving cognitive functioning was further confirmed.

Recently, a field study with soldiers was performed in Schaarsbergen (Pasman, 2005). The soldiers were supplemented with carbohydrates and caffeine. Besides physical performance, cognitive functioning was tested as well with different computer-tests. The results of this study might be useful for a more specific study at cognitive functioning and food components.

6.1.4 *Gingko Biloba and Ginseng*

Gingko Biloba, ginseng and a combination of both (Scholey and Kennedy, 2002) had positive effects on computerized serial subtraction tasks in healthy young volunteers. This study also suggests their possible positive effects on cognitive functions. However, it was not tested in a physically demanding situation.

6.1.5 *Choline*

Choline supplementation was also tested for its effect on cognitive functioning in a military setting: in this case effects on mood and marksmanship after heavy load bearing was examined (Warber et al., 1997). The overall conclusion was that mood states were not significantly changed by the administration of choline. It neither improved visual vigilance, nor shooting performance after carrying a 21 kg rucksack for 20 miles.

6.2 Conclusion

The supply of carbohydrates and caffeine has shown to improve mood and cognitive functioning in a military setting. α-Lactalbumin might be an interesting component to study in soldiers as well. Other components such as gingko biloba, ginseng, chocolate, taurine and tryptophan are not tested for their effectiveness in military physically demanding settings. Choline is not effective for improving cognitive functioning. Further studies, investigating the effect of food components on cognitive function in operational settings, should therefore be carried out using carbohydrates and caffeine.

7 Recommendations

Based on the considerations of this report, it is recommended to develop a basic research protocol. The design of the study protocol should be clear in investigating the relationship between physical load and mental performance. Furthermore, the protocol should significantly discriminate between physical load conditions and incorporate an adequate mix of performance tests, tapping those abilities that are related to military operations. The following design is proposed:

Table 1 Design possibilities for varying task durations and different physical load conditions.

	Task Duration	
Physical load	Short	Long
Low	2 hour patrol	8-10 hour patrol
High	2 hour offensive/defensive	8-10 hour offensive/defensive

This design enables to plot the discriminative properties of the proposed assessment methods in the different quadrants. Power calculations will produce minimum detectable differences and the number of subjects needed to find significant differences.

These figures will subsequently be used to design intervention studies to investigate the (positive) effects of different food components in relation to physical load and mental performance.

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9 Signature

Soesterberg, August 2005

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A Scenarios (Koerhuis et al., 2004)

Dutch airmobile brigade

Physical activities	*Physiology*	*Circumstances*
Offensive & Defensive: - loaded walking (±50kg) - alternate kneeling(±50kg) - crawling (±50kg) - backpack raising (±50kg) - digging grooves	- endurance capacity - muscular strength - upper extremity - upper leg muscles	- at night - disturbance circadian rhythm - terrain - forest/sand - environment
Peace Patrol: - loaded walking, maximally 5 km (±30kg)		

Dutch army commandos

Physical activities	*Physiology*	*Circumstances*
Special reconnaissance: - loaded walking, slowly (±50kg) - alternate kneeling/standing up - undetectable crawling (±50kg)	- endurance capacity - muscular strength - upper extremity - upper leg muscles	- environment - heat - cold - terrain - dessert - forest - mountainous
Direct action: - fighting with muscle force (close quarter combat) - lifting backpack in/out helicopter (±50kg)	- endurance capacity - muscular strength - upper extremity - upper leg muscles - co-ordination	
Supplying physical activities	*Physiology*	*Circumstances*
Mountainous terrain: - loaded walking (±50kg) - climbing/descending	- endurance capacity - anaerobic capacity - muscular strength	- altitude - low air pressure - decreased arterial oxygen pressure - earlier start of anaerobic metabolism
Watery environment: - swimming - carrying weapon on back - rowing - diving - breath hold diving - diving with oxygen	- endurance capacity - muscular strength - upper extremity - upper leg muscles	- water - increased pressure under water
HALO/HAHO: - High Altitude Low Opening jumps HALO (additional oxygen) - High Altitude High Opening jumps, HAHO (with additional oxygen) - physical performance after jump	- endurance capacity - muscular strength - upper extremity - upper leg muscles	- high altitude - additional oxygen consumption

Armoured infantry

Physical activities	*Physiology*	*Circumstances*
Offensive: - loaded running (±15kg) - alternate lying down - alternate kneeling - manoeuvring through villages/houses	- running capacity - endurance capacity - muscular strength - upper extremity - arm/shoulder - upper leg muscles	- at night - disturbance circadian rhythm - terrain - forest/sand - city/village - environment
Defensive: - loaded walking - digging	- endurance capacity - muscular strength - upper extremity - upper leg muscles	
Peace patrol: - loaded walking (±15kg)	- endurance capacity	

Dutch marines

Physical activities (Infantry)	*Physiology*	*Circumstances*
Offensive: - loaded walking (30-kg) - running - alternate lying down/standing up	- endurance capacity - anaerobic capacity - muscular strength - upper extremity - upper leg muscles	- environment - heat - cold - terrain - mountains - dessert - forest
Defensive: - loaded walk (10-15 kg) - alternate kneeling down/standing up - digging - carrying heavy materials - foot patrols (<10km, without load)	- endurance capacity - muscular strength - upper extremity - back/arms/ shoulders - upper leg muscles	
UN peace ops: - foot patrols - building projects	- endurance capacity - muscular strength - upper extremity - upper leg muscles	
Physical activities (combat support group)	*Physiology*	*Circumstances*
Offensive: - loaded walking (40-50 kg) - alternate kneeling down/standing up - digging - overcome natural obstacles - rowing - manoeuvring in small spaces	- endurance capacity - muscular strength - upper extremity - back/arms/ shoulders - upper leg muscles - flexibility	- at night - environment - heat - cold - terrain - mountains - dessert - forest
- loaded walking (10-15 kg)	- endurance capacity	

OGRV-soldiers

Physical activities	*Physiology*
Level 1: - standing	- Static muscular strength
Level 2: - patrol walking (35kg)	- Endurance capacity
Level 3: - patrol walking (40kg) - running - alternate lying down/standing up	- endurance capacity - anaerobic capacity - muscular strength - upper extremity - upper leg muscles

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15. ABSTRACT (MAXIMUM 200 WORDS (1044 BYTE))

Purpose: The relationship between physical demands, cognitive functioning, and food components is still an interesting field for research. For the Dutch Defence Organization it is important that this relationship is investigated with a special focus on military settings. Recently, attempts have been made to describe these settings in so called scenarios. However, to determine the effects of an intervention, such as food components, it is necessary to design standard test protocols. This study emphasizes the limiting conditions for these protocols and how to elaborate them in future. Method: Investigating the literature, factors were determined that play a significant role in the relationship between physical load and mental functioning. Next, realistic scenario's were selected and described, based on physical, psychological and operational demands. Using these demands a core-set of cognitive abilities was defined and performance tests were selected and further elaborated. A comparable trajectory was followed for the relationship between food components and cognitive functioning. An inventory was made consisting of food components having an effect on mental performance and a further selection was performed with respect to military settings. Results: It appears unfeasible to investigate all possible factors considering the relationship between physical and mental performance. Selections were made and it is proposed to apply a 2 x 2 factorial design, incorporating physical load (low vs. high) and task duration (short vs. long). Cognitive tasks should aim at viligance, working memory, logical reasoning, complex information processing, and psychomotor behaviour. Food components that are considered for intervention studies are carbohydrates, caffeine, and α-lactalbumin. Conclusion: Based on this report a research protocol can be designed to determine the sensitivity and magnitude of the effects with respect to the relationship between physical load and mental performance in a military setting. Next, a standardized protocol can be developed for intervention studies, such as the investigation of food components.

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