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HYDRATION AND NUTRITION REQUIREMENTS FOR PHYSICALLY DEMANDING OCCUPATIONS

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KEY POINTS

- Physically demanding occupations (PDO) require high levels of energy expenditure and technical skill to complete day-to-day tasks and training.
- Workers in PDO are at a greater risk for heat strain/illness compared to other occupations worldwide.
- The National Institute for Occupational Safety and Health (NIOSH) recommends that workers consume one cup (8 oz or 250 mL) of water every 15 – 20 min. However, fluid intake requirements vary, so workers should consider individual needs based on environmental conditions, work intensity and heat exposure duration.
- While research for nutrition requirements for PDO is somewhat limited, there is evidence that the current daily caloric intake habits of some workers may only be accounting for half of their daily energy expenditure.
- Sufficient daily intake of carbohydrates and protein is critical to maintain work performance, as well as preventing drastic changes in body composition (i.e., reduced lean body mass).
- Education for workers on appropriate pre-, on- and post-shift fluid and nutrition consumption may represent a practical and effective means to maintain occupation performance and worker health.

INTRODUCTION

Physically demanding occupations (PDO) are both physically and cognitively straining. These occupations, which include positions in structural and wildland firefighting, agriculture, construction, manufacturing and the military, require high levels of energy expenditure, mental awareness and technical skill to complete their work, while also potentially being exposed to extreme environmental challenges such as heat and/or high altitude (Figure 1). The extreme environmental conditions can have severe consequences on worker health. Specifically, a recent meta-analysis reported that 35% of American PDO workers experienced occupational heat strain (i.e., experienced at least one occupational heat strain symptom, as defined by International Health and Safety guidelines (ISO, 2004)) during or following the work shift and 30% of workers reported productivity loss due to heat strain symptoms (Flouris et al., 2018). Along with the environmental stress factors, studies have suggested that those in PDO, such as the military (Margolis et al., 2013) or wildland firefighting (Marks et al., 2020), may not be consuming sufficient calories to keep up with the demands of their daily tasks. For instance, it is reported that United States Special Force Soldiers may be operating under as much as a 52% energy deficit on a day-to-day basis (Margolis et al., 2013). Collectively, with the known physical and cognitive demands of these occupations, PDO workers also need to contend with the environmental strains and energetic deficits that can severely impact work performance (Figure 1).

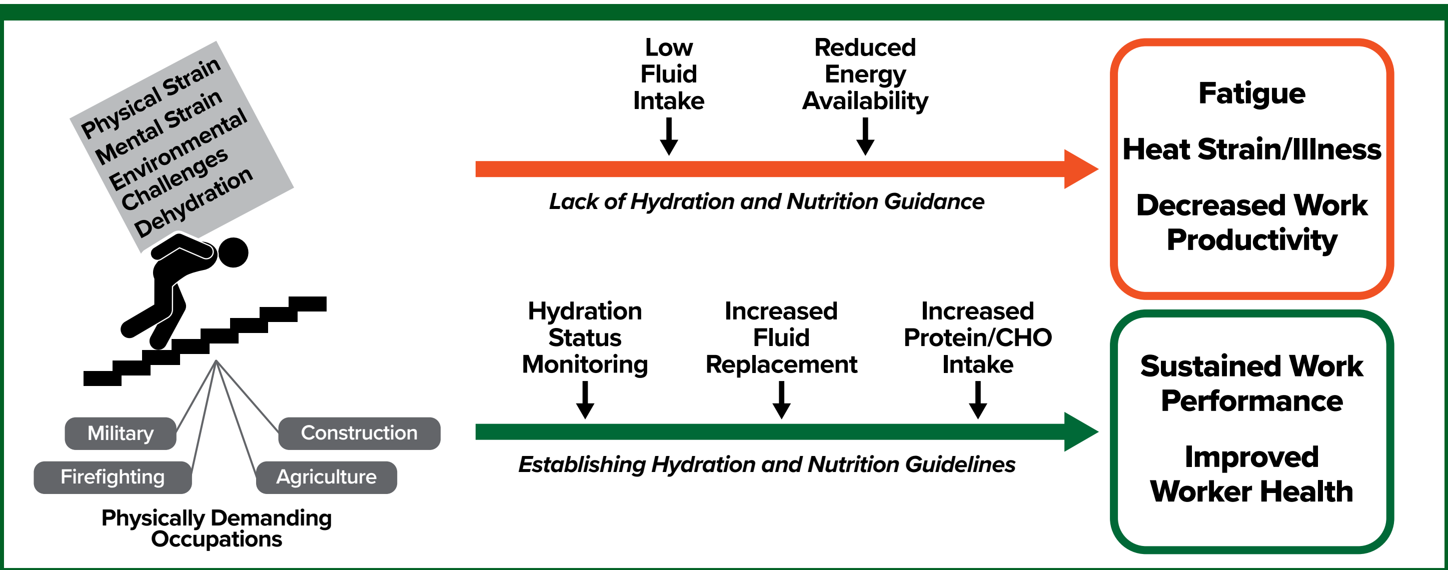


Figure 1: Importance of Fluid and Nutrition Guidelines in Physically Demanding Occupations. CHO, carbohydrate.

In general, hypohydration may lead to an increased risk of heat-related illness (Mansor et al., 2019), decreased hypovolemia and hemorrhagic injury tolerance (Lucas et al., 2013; Schlader et al., 2015), reduced cognitive function and alertness (Adan, 2012; Ganio et al., 2011) and reduced physical work capacity and productivity (Cheuvront & Kenefick, 2014; Jacklitsch et al., 2016). Likewise, low energy intake may lead to decreases in aerobic capacity (Guezennec et al., 1994), reduced bone formation (Hughes et al., 2014), impairments in cognitive tasks such as attention, reaction time, memory, reasoning and vigilance (Lieberman et al., 2005) and increases in fatigue (Lieberman et al., 2009) and depression (Gifford et al., 2019; Lieberman et al., 2009). Despite the known environmental challenges and energetic demands of these occupations, PDO workers have received limited attention regarding their hydration and nutrition needs to sustain work performance and promote overall health in comparison to other cohorts, such as athletes. Therefore, the purpose of this Sports Science Exchange (SSE) article is to provide a brief review of the literature and summarize the knowledge gaps and future research investigating hydration and nutrition requirements for physically demanding occupations.

PHYSIOLOGICAL DEMANDS

Proper hydration and nutrition recommendations require an understanding of the physiological demands of the tasks in an occupation, as well as the total daily energy expenditure of the individual. For example, previous research has indicated that the average individual who works at a desk for a majority of their shift only expends about 72 kcal·h^{-1} (Levine & Miller, 2007). By comparison the average PDO worker may expend upwards of 360 kcal·h^{-1} (Poulianiti et al., 2019). While research is limited for some PDO, previous studies have provided some insight on the energy requirements for positions in the military, firefighting, construction and agriculture.

Military

In tactical settings, military tasks range from those that rely heavily on the anaerobic system (e.g. sprinting and heavy lifting), requiring high levels of power, speed and agility; to those that are primarily aerobic, requiring increased levels of endurance (Alvar et al., 2017). This wide range in task variability is only amplified by external factors such as sleep deprivation, psychological stress, extreme environmental conditions and extended duration of activity (Alvar et al., 2017). Previous studies have used doubly labeled water to investigate differences in average daily energy expenditure for military active-duty service members (ADSM) based on sex (Mudambo et al., 1997; Tharion et al., 2005) and role (Barringer et al., 2018; Bovill et al., 2002; Margolis et al., 2013). Specifically, previous studies assessing the metabolic demands for military ADSM in the field reported daily energy expenditures ranging from 13 to 28 MJ·day^{-1} (3,109 – 7,131 kcal·day^{-1}) and 9.8 to 23.4 MJ·day^{-1} (2,332 – 5,597 kcal·day^{-1}) for men and women, respectively (Mudambo et al., 1997; Tharion et al., 2005). This wide range in daily energy expenditure amongst military ADSM may be due to discipline-specific demands, as the average daily energy expenditure for special force soldiers has been reported to be ~4,100 kcal·day^{-1}, which is 22% higher than the reported value for support soldiers (~3,361 kcal·day^{-1}) (Bovill et al., 2002). Yet, metabolic demands may also vary within military disciplines due to task-specific metabolic demands, with daily energy expenditures ranging from 3,500 to 7,000 kcal·day^{-1} within special operations forces (Barringer et al., 2018; Margolis et al., 2013).

Firefighting

Wildland firefighting is one of the few occupations that require elevated levels of strength and endurance over extended durations, forcing firefighters to sustain elevated energy expenditures for 12-16 hours·day^{-1} over consecutive days (Sol et al., 2018). Previous studies have reported daily energy expenditures ranging from 12.3 to 26.2 MJ·day^{-1} (2,946 – 6,260 kcal·day^{-1}) and 11.4 to 20.6 MJ·day^{-1} (2,719 – 4,920 kcal·day^{-1}), for men and women wildland firefighters, respectively (Cuddy et al., 2014; Ruby et al., 2002). Another study investigating the cardiorespiratory demands of wildland firefighting cited oxygen consumption (VO_2) values ranging from 19 to 22 mL·kg^{-1}·min^{-1} during job-related hikes and an average VO_2 of 34 mL·kg^{-1}·min^{-1} during training hikes (Sol et al., 2018). Elevated cardiovascular demands have also been observed in structural firefighters, reporting VO_2 values as high as 38.5 and 36.6 mL·kg^{-1}·min^{-1} for men and women, respectively, during the Candidate Physical Ability Test (CPAT) (Williams-Bell et al., 2009). While only sustained over a short period of time (i.e. ~8 - 11 min), this corresponds to 73% and 71% of their respective maximum oxygen uptakes (VO_2max) (Williams-Bell et al., 2009). In emergency rescue situations lasting over 15 min, firefighters have been shown to sustain oxygen consumption values of ~63% of their respective VO_2max (Sothmann et al., 1992). Additionally, a recent report examining the physiological cost of firefighting found that the metabolic demand of fire suppression tasks may reach 11.9 metabolic equivalents (METs) (41.7 mL·kg^{-1}·min^{-1}), with a minimum of 7.3 METs (25.6 mL·kg^{-1}·min^{-1}) (Morris & Chander, 2018), which is comparable to that of ice hockey, lacrosse and soccer players in their respective sport (Jetté et al., 1990).

Construction

As of 2020, 10.8 million Americans were employed within some aspect of the construction industry (Gallagher, 2022), which is roughly equal to the population of the state of Georgia, USA (USCB, 2021). A previous report assessing the physiological demands of various PDO suggested that the work related tasks within the construction industry require a high rate of energy expenditure (~4.9 kcal·min^{-1}) (Poulianiti et al., 2019), which is similar to the average absolute VO_2 of ~0.82 L·min^{-1} (~4.1 kcal·min^{-1}) reported in an earlier study assessing VO_2 during construction work (Abdelhamid & Everett, 2002). These reports suggest that the average daily tasks of construction workers elicit comparable metabolic responses to that of light weight training or ice skating (Jetté et al., 1990). Moreover, when the perspective is moved to daily energy expenditure, construction workers expend an average of ~12.68 MJ·day^{-1} or ~3,074 kcal·day^{-1}(Haggarty et al., 1997). While the average daily expenditure for construction may be slightly lower than those of other PDO, the long shifts (i.e. 8 – 12 hours), paired with inadequate fluid intake (Piil et al., 2018), can cause workers to become physically fatigued, leading to decreased productivity, which is exacerbated by increased environmental temperature (i.e. 2.6% decreased productivity per 1°C increase in temperature) (Morrissey et al., 2021).

Agriculture

Representing 27% of the world's labor force (ILO, 2021), agricultural work is one of the most metabolically demanding industrial occupations (Poulianiti et al., 2019). Specifically, one study found that agricultural workers experienced higher caloric expenditure rates than those in the construction and manufacturing industries, citing rates up to ~6.0 $kcal \cdot min^{-1}$ (Poulianiti et al., 2019), which is comparable to that of doubles tennis or singles badminton players in their respective sport (Jetté et al., 1990). Yet, when the focus is shifted to daily energy expenditure, one previous study focusing on agriculture in desert climates found that workers expended up to 3,400 $kcal \cdot day^{-1}$ (Brun et al., 1979). Thus, this strenuous physical work, along with heat stress and hypohydration, due to chronic exposure to environmental conditions that exceed human thermoregulatory capacity (wet bulb globe temperature > 30°C), can lead to severe medical conditions, including an increased prevalence of chronic kidney disease (CKD) (Flouris et al., 2018; Weiner et al., 2013).

FLUID INTAKE REQUIREMENTS

The National Institute for Occupational Safety and Health (NIOSH) has defined occupations such as agriculture, construction, firefighting and manufacturing at greater risk for heat stress compared to other occupations in the United States (Morrissey et al., 2021). A recent analysis of injuries and fatalities reported to Occupational Safety and Health Association (OSHA) in the United States from 2015 – 2020 indicated that up to 85% of all exertion-related (i.e., not accidents or intent to harm) injuries were heat-related cases (Morrissey et al., 2023). Improper hydration can impair the body's ability to remove heat, leading to increased cardiovascular strain and glycogen use, altered metabolic and central nervous function and decreased fluid absorption (Thomas et al., 2016). Research has shown that a > 2% reduction in body mass from sweating may impair cognitive and aerobic performance (Cheuvront & Kenefick, 2014; Thomas et al., 2016), with a 3 - 5% reduction in body mass leading to additional impairment to anaerobic performance and motor skills (Thomas et al., 2016). It is imperative that PDO workers replace the fluid lost through sweat throughout their shift to avoid hypohydration (> 2% body mass loss), especially when exposed to hot temperatures for prolonged periods (Brake, 2003). Previous studies have indicated that individuals in various PDO experience average whole body sweating rates (WBSR) of ~1 $L \cdot h^{-1}$ (Jacklitsch et al., 2016; Montain et al., 1999), which is similar to basketball and soccer athletes in their respective sport (Barnes et al., 2019). Therefore, the current NIOSH fluid intake guidelines for PDO suggest consuming one cup (8 oz or 250 mL) of fluid, preferably water, every 15 to 20 min or about 1 $L \cdot h^{-1}$ (Jacklitsch et al., 2016). Additionally, NIOSH recommends that sport drinks containing electrolytes and < 8% carbohydrates should be used in place of water when workers are exposed to a hot environment for prolonged periods (≥ 2 hours) (Jacklitsch et al., 2016).

Occupation	Study	Environmental Conditions		Activity	Pre-Shift USG	Rate of Sweat Loss ($L \cdot h^{-1}$)	Body Mass Loss (%)
		Temperature	RH				
Military ADSM	(Montain et al., 1999)	28.0°C	75.0%			Men: 0.62 ± 0.10 Women: 0.52 ± 0.14	
		32.0°C	75.0%	Moderate Intensity Walking Exercise Test (425W)	N/A[a]	Men: 0.77 ± 0.14 Women: 0.60 ± 0.14	N/A[a]
		36.0°C	75.0%			Men: 1.10 ± 0.13 Women: 0.72 ± 0.35	
Structural Firefighting	(Walker et al., 2019)	40.0°C @ 0.3 m* 130.0 - 155.0°C @ 1.1 m* 458.3°C @ 2.6 m*	53.1%	15-min 'Live' Fire Scenario • Low Posture Victim Drag • Hose Drag	1.016 ± 0.010	3.04	-1.27
Industrial Labor	(Miller & Bates, 2007)	26.9 – 42.9°C	50.0 – 60.0%	Machine Operators Construction Manual Labor (Various Tasks)	1.023 ± 0.005 1.018 ± 0.008 1.025 ± 0.006	0.375 ± 0.12 1.030 ± 0.36 0.376 ± 0.09	-0.96 ± 0.59 -0.01 ± 1.55 -0.34 ± 0.67
	(Biggs et al., 2011)	21.1°C	67.0%	Forestry: Chainsaw Operators Chainsaw Assistants Stackers Debarkers	1.018 ± 0.007 1.018 ± 0.009 1.018 ± 0.007 1.018 ± 0.006	N/A[a]	-2.00 – -3.00
		17.0°C	39.0%	Chainsaw Operators Chainsaw Assistants Rough Liners	1.019 ± 0.004 1.024 ± 0.005 1.020 ± 0.007	N/A[a]	-2.00 – -3.00

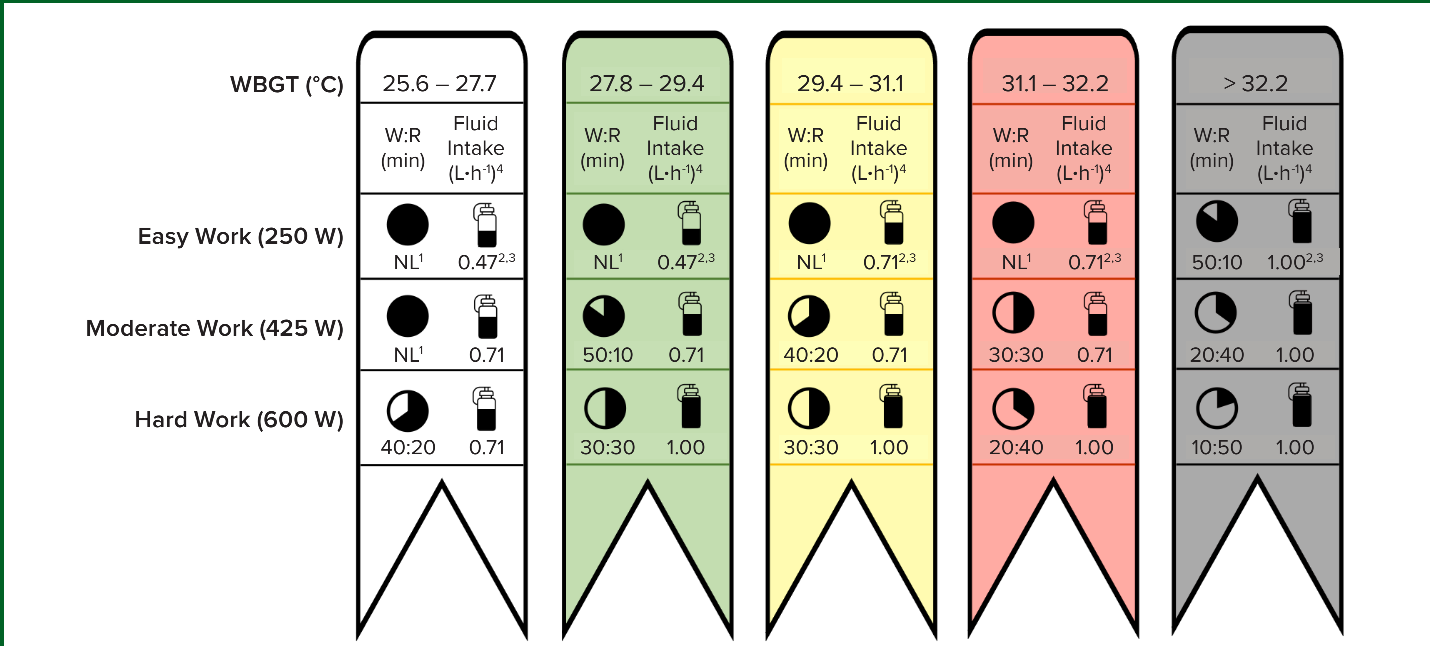
*Measured Height from Ground; [a]Not a Measured Outcome; ADSM = Active-Duty Service Member; RH = Relative Humidity.

Table 1: Previous Observed Rates of Sweat Loss ($L \cdot h^{-1}$) and Body Mass Loss (%) for Physically Demanding Occupations.

While these general guidelines serve as a starting point, the diverse physiological demands and environmental conditions of different PDO, as well as individual characteristics of workers, elicits varied fluid intake requirements. Previous research investigating average rates of sweat and body mass loss for various PDO have reported a wide range of values (Table 1). Specifically, average sweat loss for military ADSM during moderate activity in mild to hot conditions can range from 0.62 – 1.10 and 0.52 – 0.72 $L \cdot h^{-1}$ for men and women, respectively (Montain et al., 1999), with similar rates of sweat loss being observed in construction workers (~1.03 $L \cdot h^{-1}$) under similar environmental conditions (Miller & Bates, 2007). Meanwhile, considerably higher rates of sweat loss (3.04 $L \cdot h^{-1}$) have been seen in structural firefighters during a 15-min 'live' fire scenario (Walker et al., 2019). Additionally, another study found that those in the forestry occupations may lose 2 - 3% body mass over the duration of a shift, even during the cooler parts of the year (i.e., autumn and winter) (Biggs et al., 2011).

Current fluid intake recommendations for military ADSM (Figure 2) have been shown to effectively predict the amount of fluid needed to maintain a euhydrated state (i.e., < ±2% body water flux) (Luippold et al., 2018). However, the current fluid intake guidelines are based on recommended work-to-rest ratios (W:R), which can vary with changes in temperature, relative humidity (RH) and work intensity (Luippold et al., 2018). Therefore, in cases where following the recommended W:R for a given heat category is not possible, additional fluid intake may be required to maintain proper hydration. Additionally, since fluid intake needs may vary depending on individual differences (e.g., sex) (Luippold et al., 2018) or environmental conditions (e.g., sun exposure, RH) (Luippold et al., 2018; Montain et al., 1999), it is suggested that actual fluid needs may vary by ± 0.24 $L \cdot h^{-1}$ (Luippold et al., 2018).

While current fluid intake guidelines are designed to prevent dehydration while on the job (Jacklitsch et al., 2016), additional challenges arise when workers arrive hypohydrated. While spot urine checks can produce false negatives and positives due to acute, uncontrolled, changes in body water (Cheuvront et al., 2015), urine-specific gravity (USG) (i.e., the measure of the concentration of solutes within urine) has been used in numerous studies to assess levels of hypohydration for PDO both pre- and post-shift (Biggs et al., 2011; Brake, 2003; Miller & Bates, 2007; Mix et al., 2018). Previous studies have reported that 43 – 53% of agricultural workers may arrive to their shift hypohydrated (USG ≥ 1.020) (Biggs et al., 2011; Mix et al., 2018). Specifically, 53% of agricultural workers in Florida, USA displayed USG values that may be indicative of hypohydration upon arrival to the work site and 83% displayed similar values at the end of their shift (Mix et al., 2018), which suggests that the current fluid intake habits of these agricultural workers may not be enough to elevate them from a hypohydrated state and keep them hydrated throughout their shift. Similarly, another study revealed that 70% of urine samples from outdoor workers in Northwest Australia indicated inadequate hydration levels (USG > 1.020) prior to starting their work shift, with 50% being severely hypohydrated (USG ≥ 1.026) (Miller & Bates, 2007). Moreover, another study investigating the hydration status of Australian industrial workers found that 56% of workers arrived to their shift with a USG greater than 1.022 and 9% of workers arriving with a USG greater than 1.030 (Brake, 2003). Collectively, these results indicate that, along with improving fluid intake



W:R Symbol (Black = Work; Color = Rest); Fluid Intake Symbol (Black = Recommended Volume); [1]No limit to work time per hour (up to 4 continuous hours); [2]Hourly fluid intake should not exceed 1.42 $L \cdot h^{-1}$; [3]Daily fluid intake should not exceed 11.36 L; [4]Fluid needs can vary based off individual differences and sun exposure (±0.24 $L \cdot h^{-1}$); NL = No Limit, WBGT = Wet Bulb Globe Temperature, W:R = Work-to-Rest ratio. (Luippold et al., 2018)

Figure 2: Fluid Intake and Work: Rest Recommendations for Military ADSM in Warm Weather.

during working hours, there is a pressing need to better educate PDO workers on proper pre-shift hydration to decrease the risk of heat illness and impaired performance.

NUTRITION REQUIREMENTS

Energy availability

Total daily energy requirements for PDO vary, depending on age, biological sex, body composition, environmental conditions and activities performed. Specific energy requirements should be based on daily energy expenditure and the energy demands of job-related tasks, along with the energy demands of training to maintain strength and endurance (Alvar et al., 2017). While limited research has been conducted on the nutritional requirements for various PDO, previous studies have investigated the average daily caloric intake for military ADSM (Margolis et al., 2013; Pasiakos et al., 2013) and wildland firefighting (Marks et al., 2020). For example, by calculating the difference between available energy in uneaten foods and known energy in individually packaged rations, average energy intake values ranging from 2,510 – 3,633 kcal·day^{-1} have been observed in United States Special Forces soldiers during training events (Margolis et al., 2013). Interestingly, using doubly labeled water, these soldiers had estimated daily energy expenditure values ranging from around 3,500 - 7,000 kcal·day^{-1}, indicating that military ADSM may be operating under an energy deficit of up to 52% (~2,700 kcal·day^{-1}) (Margolis et al., 2013). This would suggest that some job-related tasks may require military ADSM to double their daily caloric intake to keep up with the metabolic demand. Similar energy deficits have been observed in wildland firefighters, with one study reporting average energy intake values of only ~1,494 kcal while on duty (14-hr shifts) (Marks et al., 2020). While this energy intake value only represents any food consumed on duty, it is suggested that the current caloric intake habits of wildland firefighters may not be providing adequate energy for occupational demands. The following section describes the current recommendations for macronutrient (carbohydrate, protein and fat) intake for PDO workers.

Carbohydrates

The United States Department of Agriculture (USDA) recommends that all adults acquire 45 – 65% of their total daily calories via carbohydrates (USDA & HHS, 2020). For PDO, the National Strength and Conditioning Association (NSCA) has previously suggested that military ADSM consume 4 - 7 g·kg^{-1} and 8 - 12 g·kg^{-1} of body weight per day of nutrient-dense, minimally processed carbohydrates for the completion of strength based and endurance based tasks, respectively (Alvar et al., 2017). However, due to a lack of research, there are currently no specific carbohydrate intake recommendations for other PDO.

Nevertheless, the prolonged shifts that are associated with these occupations may require workers to complete moderate to vigorous activity for more than 12 hours (Alvar et al., 2017; Sol et al., 2018). As previous research has suggested a negative correlation between duration of vigorous activity completed and muscle glycogen availability (Cuddy et al., 2011), it is imperative for PDO to replace carbohydrate stores throughout their shift to prevent impairments in physical performance (Costill & Miller, 1980). Therefore, to replace the carbohydrates that are used for fuel, PDO workers may consider following the guidelines set for endurance athletes as part of the 2016 Joint Position Statement on Nutrition and Athletic Performance from the Academy of Nutrition and Dietetics (AND), Dieticians of Canada (DC) and American College of Sports Medicine (ACSM) (Thomas et al., 2016). These guidelines recommend athletes consume 30 – 60 g·h^{-1} of carbohydrates when the duration activity is between 1 – 2.5 hours, increasing intake to 90 g·h^{-1} if activity is sustained for > 2.5 – 3 hours (Thomas et al., 2016). However, carrying sufficient fuel sources to keep up with the demand may become difficult when workers are continuously on the move in the field (i.e., training hikes or spike camps). Therefore, viable food options must include those that are 1) portable, 2) lightweight, 3) energy/nutrient dense, 4) non-perishable and 5) not easy to melt, including dried fruit, crackers, fruit snack and sport foods (Table 2).

Protein

Adequate consumption of dietary protein is necessary to support muscular adaptations, including muscle repair, remodeling and protein turnover (Thomas et al., 2016). The USDA currently recommends for all adults to obtain 10 – 35% of their total daily calories from protein (USDA &

- Trail Mix[1] (nuts, seeds, dried fruits)
- Jerky
- Granola or Energy Bars
- RTE Cereals
- Nut Butter Packets
- Chicken or Fish Packets (w/ Shelf Stable Mayonnaise)
- Dried Fruits/Vegetables
- Tortilla Wraps[2]
- Crackers[3]
- Fruit Snacks or Candy[1]
- Sport Foods (Gummies/Gels)

[1]Avoid chocolate or other ingredients that melt in the heat; [2]Choose non-perishable fillings (i.e., peanut butter or honey); [3]Store in container to prevent from being crushed; RTE = Ready-to-Eat

Table 2: Potential Food Options for Work in the Field.

HHS, 2020), aiming to consume at least the current recommended daily allowance of 0.8 $g \cdot kg^{-1}$ of body weight per day to avoid protein-related deficiencies (i.e., muscle loss and nitrogen level imbalances) (Phillips et al., 2016). However, research suggests that consuming an additional 0.8 $g \cdot kg^{-1}$ of body weight above recommended dietary allowance values may attenuate the loss of lean muscle mass by influencing the intracellular regulation of muscle anabolism and proteolysis (Carbone et al., 2012). Therefore, to promote muscle protein synthesis and prevent the loss of lean muscle mass, a higher daily protein intake of 1.4 – 1.6 $g \cdot kg^{-1}$ of body weight has been recommended, with higher intakes of up to 2.0 $g \cdot kg^{-1}$ of body weight being indicated for short periods of intensified training or energy deficits (Phillips, 2013; Thomas et al., 2016). Likewise, to maintain muscle mass, strength and performance during periods of substantial metabolic demand and associated negative energy balance, previous research has recommended that military ADSM should consume 1.5 – 2.0 $g \cdot kg^{-1}$ of body weight per day (Pasiakos et al., 2013).

Along with total daily intake, the source of dietary protein must also be considered. Previous research suggests that whole milk, lean meat, plant proteins and select isolates (i.e., whey, casein, egg and soy) increase muscle protein synthesis and protein accretion (Nichele et al., 2022; Pennings et al., 2011; Phillips, 2013; Thomas et al., 2016). Dairy protein seems to be superior to other protein sources (i.e., plant proteins), mainly due to the leucine content, as well as, the digestion and absorptive kinetics of branched-chain amino acids in fluid-based dairy products (Pennings et al., 2011). However, recent evidence suggests that, when combined with different food groups to ensure adequate intake of essential amino acids and leucine, plant-based proteins may also be a viable nutritional source to support muscle mass (Nichele et al., 2022). Nonetheless, if whole food protein sources are not available in the field or on the jobsite, portable dietary supplements (i.e., isolate protein bars and powders) made from high-quality ingredients may serve as a practical alternative for dietary protein intake (Thomas et al., 2016).

Fat

Currently, the USDA recommends that dietary fat consumption for adults account for 20 – 35% of daily caloric intake (USDA & HHS, 2020). While no specific guidelines for PDO have been recommended, the NSCA cites that the correct type (i.e., unsaturated fats) and amount of fat is critical for military ADSM and can be significant in situations when access to food or time to consume meals are limited (i.e., field training and combat) (Alvar et al., 2017). When planning meals, consider including nuts, seeds and fish as good sources of unsaturated fat, avoiding cured meats or products that contain partially hydrogenated oils (i.e., commercial baked goods). Moreover, to make sure individuals receive valuable fat-derived nutrients (i.e., fat-soluble vitamins, essential fatty acids, etc.), it is recommended that individuals avoid chronic implementation of fat intakes below 20% of energy intake (Thomas et al., 2016).

KNOWLEDGE GAPS

Currently, there is a significant amount of research outlining the physiological demands for military ADSM, firefighters and agriculture and construction workers, but for other PDO, such as manufacturing workers, less is known. Future research investigating the physiological demands of these workers may provide valuable insight on how to better incorporate hydration and nutrition strategies across various PDO. Moreover, since previous research has indicated that agricultural workers tend to arrive to their shift hypohydrated, future research investigating how to better educate PDO workers on proper pre-shift hydration strategies is warranted.

Additionally, there are currently significant knowledge gaps pertaining to the nutritional recommendations for firefighting, agriculture and construction as it pertains to work performance and overall health and nutrition. Future research investigating specific caloric and macronutrient intake values may provide valuable insight on how to establish nutritional guidelines for these PDO.

PRACTICAL APPLICATIONS

- Understanding fluid losses via sweat testing within PDO would allow for better hydration recommendations, leading to increased worker productivity and decreased risk of heat strain/illness.
- When exposed to hot environments for longer than two hours, those in PDO should consume an electrolyte containing beverage in place of water.
- Educating workers on appropriate pre- and on-shift fluid consumption may represent a practical approach for reducing on-shift dehydration.
- Nutritional guidelines for military active-duty service members (ADSM) should include consuming 4 – 7 $g \cdot kg^{-1} \cdot day^{-1}$ and 8 – 12 $g \cdot kg^{-1} \cdot day^{-1}$ of carbohydrates for strength and endurance-based tasks, respectively.
- Consuming an additional 0.8 $g \cdot kg^{-1} \cdot day^{-1}$ (1.4 – 1.6 $g \cdot kg^{-1} \cdot day^{-1}$ total) of protein above the current recommended daily allowance can protect against lean muscle mass attenuation.
- When working in the field, pack portable, lightweight, energy/nutrient dense, non-perishable and not easy to melt meals and snacks to meet energy demands.

SUMMARY

Understanding the physiological and metabolic demands of the tasks encompassed in an occupation is essential for determining proper hydration and nutrition guidelines. With high physical and mental demands, PDO are currently some of the most energetically demanding professions worldwide. Further, due to the environmental and energetic stressors associated with various professions, PDO workers are at a greater risk for heat stress and energy deficits, both key contributors to reduced work performance and greater risk of developing health complications. Unfortunately, beyond military ADSM, there is a lack of consensus of hydration and nutritional guidelines for PDO workers in various professions (construction, firefighting, agriculture, etc.). With a growing number of individuals in these professions, along with greater environmental stressors (i.e., high heat and humidity), it is critical to better understand the hydration and nutritional needs of PDO workers to optimize work performance.

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