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SITTING DUCKS: PHYSICAL ACTIVITY AND DIET-RELATED INTERVENTIONS IN THE "PERI-COVID-19" PERIOD

TELESNA DEJAVNOST IN PREHRANSKE SMERNICE V ČASU COVIDA-19

ABSTRACT

The global coronavirus disease 2019 (COVID-19) poses specific challenges for physically-active cohorts of people. Students, adults, and the elderly need to adapt and seek proper physical activity and diet-related interventions to use their spare time effectively and/or improve their health. Not surprisingly, the existing body of knowledge reveals a consensus on the importance of proper nutrition and physical activity in the so-called "peri-COVID-19" period (i.e., before, during, and after the coronavirus pandemic); however, we explain context-dependent considerations. Therefore, the present study provides a brief review of current knowledge of physical activity and nutrition and develops a three-stage conceptual model for context-based guidelines. The model pinpoints the relative importance of parameters of physical activity in three different periods. In addition, we provide illustrative examples of appropriate training regimens. Our findings complement the agenda for individuals willing to establish desired physical condition and nutrition after the pandemics. Finally, we reveal the supportive role of diet-related interventions and supplements in the peri-COVID-19 period.

Keywords: COVID-19, physical activity, nutrition, guidelines, model

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IZVLEČEK

Razsežnost koronavirusne bolezni (COVID-19) predstavlja specifične izzive za različne skupine aktivnih posameznikov. Študentje, odrasli in starejši odrasli se morajo prilagoditi in s prehranskimi intervencijami ter redno telesno dejavnostjo izkoristiti čas učinkovito ter ob tem izboljšati zdravje. Pretekle raziskave kažejo na vlogo oz. pomen ustrezne prehrane in telesne dejavnosti v obdobju pred, med in po COVIDU-19 ("peri-COVID-19"), vendar je potrebno ugotovitve relativizirati in opredeliti. Pričujoča študija zatorej ponuja kritičen pregled literature na področju relevantnih dejstev o telesni dejavnosti in prehrani ter razvije 3-stopenjski konceptualni model za boljše razumevanje smernic v celotnem obdobju COVIDA-19. Z modelom ponazorimo relativne razlike med posameznimi fazami in s primeri dodatno pojasnimo, kako ustrezno načrtovati prehrano in vadbo v t. i. peri-COVID-19 obdobju. Z našimi ugotovitvami in pregledom potencialne vloge prehranskih dopolnil lahko posamezniki bolje oblikujejo telesno pripravljenost in se predvidoma uspešneje vrnejo k zdravemu življenjskemu slogu po pandemiji koronavirusne bolezni.

Ključne besede: COVID-19, telesna dejavnost, prehrana, smernice, modeliranje

INTRODUCTION

Since antiquity, when Hippocrates warned that proper nutrition alone would not keep a person healthy, regular physical activity has been known to positively affect physical and mental health (Berryman, 2010). From the physiological perspective, any event that requires the consumption of energy as a result of skeletal muscle contraction is physical activity (Caspersen, Powell & Christenson, 1985). Physical activity is thus any activity that raises the heart rate and can be implemented in the form of sports, for instance walking to school or work, playing with friends, family, dancing, or other workouts (Roberts, Tynjala & Komkov, 2004). Physical activity positively impacts a person's development if it is frequent and of sufficient quality, intensity, and duration (Goh, Lim & Suzuki, 2019; Haskell et al., 2007).

Physical activity and nutrition improve physical health, well-being, quality of life, and cognitive performance (Arena et al., 2018; Hazzard et al., 2020; Kraemer, Ratamess & French, 2002; O'Connor, Paddon-Jones, Wright & Campbell, 2018; Powell & Pratt, 1996; Swift et al., 2013; Theodore et al., 2020). The technological and social developments of recent decades have led to major lifestyle changes (Ryden, 2015); compared to the generations of our parents or grandparents, to whom physical activity, from physical transport to hard work, was part of everyday life, the current environment not only reduces the need for such physical activity but also encourages sedentary behaviors and entices individuals into unhealthy dietary choices (Keim, Blanton & Kretsch, 2004; Owen, Sparling, Healy, Dunstan & Matthews, 2010). Consequently, people's energy expenditure has been gradually reducing (Hill, Wyatt, Reed & Peters, 2003; Tremblay, Colley, Saunders, Healy & Owen, 2010). The coronavirus pandemic inevitably increases sedentary lifestyle by establishing the need to quarantine individuals, and thus poses cumbersome challenges to designing physical activity appropriately (Khoramipour et al., 2020). More importantly, a growing body of evidence emphasizes the role of proper nutrition, medical support, and healthy lifestyles in pre-disease and during the period of infection to more effectively cope with COVID-19 (see, e.g., Aman & Masood, 2020; Jordan Ministry of Health, 2020; Khoramipour et al., 2020).

Much attention has been devoted to analyzing patients' fitness when hospitalized (or self-isolated) because of the global COVID-19 pandemic. To the best of our knowledge, the severity of the disease was linked to prior health-related issues such as pre-diabetes, prolonged hyperglycemia, type-2 diabetes, hypertension, obesity, and other chronic diseases (see, e.g., Brufsky, 2020; Surveillances, 2020). The avoidance of a sedentary lifestyle should be of key

importance for individuals in quarantine (Rynders, Blanc, DeJong, Bessesen & Bergouignan, 2018), especially as the growing body of evidence demonstrates the role of metabolic dysfunction and associated metabolic states to severe cases of COVID-19 (see, e.g., Targher et al., 2020). In addition, a sedentary lifestyle and poor diet choices are reliable predictors of weight gain (Booth, Rowlands & Dollman, 2015; Hruby et al., 2016; Rynders, Blanc, DeJong, Bessesen & Bergouignan, 2018; Sigmund et al., 2018), several forms of cancer (Gilchrist et al., 2020), chronic non-communicable diseases, including the risk of coronary heart disease (Batty & Lee, 2004), and COVID-19 susceptibility (Butler & Barrientos, 2020).

While the benefits of limiting sedentary behavior are intuitive, we address the ambiguities regarding the recommendations for coping with the sedentary lifestyle before, during, and after the coronavirus pandemic ("peri-COVID-19 period"). We differentiate between three time spans due to their inherent differences. The before stage is characterized by little to no barriers to being physically active and the probability of an average individual becoming infected with SARS-CoV-2 limited to zero. In the during stage, several limitations, such as mandatory staying at home or within one's county, exist and can prevent individuals from remaining as active as they previously were. In addition, the diet selection is expected to be poorer and lower, while the probability of an average individual to become infected rises considerably with a coronavirus pandemic. Drawing on the previous pandemics and anticipating and depicting near-future agenda, we consider the after stage as a period in which an average individual's physical activity (or condition), as well as the probability of becoming infected, is lower, while the barriers for physical activity are either non-existent or pose a little danger to preventing an individual from establishing and maintaining a level of physical activity similar to the one prior to the pandemic.

In the remainder of the study, we describe the existing body of knowledge to pinpoint potential differences in designing training regimens (e.g., moderate vs. vigorous bouts of exercise) and diet choices in the peri-COVID-19 period. By so doing, the aim of this study is thus three-fold. First, we review the literature on physical activity and general nutritional guidelines, emphasizing sedentary populations. Second, we contextualize the findings and develop a conceptual model to complement the existing guidelines concerning specific time-dependent interventions advised. Third, the current study discusses the potential to-be state after the coronavirus pandemics concerning physical activity and nutrition and provides a salient agenda for individuals whose goal is to increase activity and improve conditioning in the future.

THEORETICAL BACKGROUND

Physical fitness and physical activity

Physical fitness represents the level of physical ability that enables a person to operate independently and efficiently in everyday life, and it is closely related to health (Ortega, Ruiz, Castillo & Sjöström, 2008). Poor physical fitness has been associated with the risk of early cardiovascular death, which strongly suggests that physical fitness may modulate cardiovascular death risk (Engeseth et al., 2018). Physical inactivity is currently one of the most common causes of premature mortality (World Health Organization, 2020).

Evidence shows that even occasional high-intensity physical activity enhances immune responsiveness because it leads to increased antibacterial and antiviral immunity (Campbell & Turner, 2018). Research suggests that physical activity, which lowers systemic inflammatory activity and enhances aspects of immune function, leads to adjustments in the biomarkers of an aging immune system (Abramson & Vaccarino, 2002; Kasapis & Thompson, 2005). These changes could be interpreted as limiting or delaying immunological aging (Simpson, 2011; Simpson & Guy, 2010; Turner, 2016; Turner & Brum, 2017).

Research on proper (context-based) recommendations about physical activity during the coronavirus pandemic is scarce, although it is quite intuitive that the effects and measures implemented by governments worldwide to combat the COVID-19 will adversely impact the duration, intensity, and frequency of physical activity (Lippi, Henry & Sanchis-Gomar, 2020).

In the remainder of the chapter, Table 1 summarizes the available general guidelines concerning physical activity from the literature. Drawing on both the physical-activity and general nutritional guidelines, we then proceed to the development of a three-stage conceptual model.

Table 1. Excerpts of relevant general guidelines for peri-COVID-19 physical activity.

1.	Make physical activity a compulsory part of your daily schedule (Buchman et al., 2012; Church et al., 2011; Jurak et al., 2020; World Health Organization, 2010).
2.	Gradually work towards increased frequency, duration, and intensity (Hull, Loosemore & Schwellnus, 2020).
3.	Minimize sedentary time with short bouts of physical activity at home (Pinto, Dunstan, Owen, Bonfa & Gualano, 2020; Khoramipour et al., 2020; Warren et al., 2010).
4.	Prioritize adherence (the continuity and regularity) rather than the intensity of the physical activity (Ricci et al., 2020; Turner & Brum, 2017).

5.	Elderly people at greater risk of infection should perform light-intensity exercises to stimulate muscles and flex joints (World Health Organization, 2010), while the sedentary population, in general, should avoid exhausting exercise during pandemics (Shephard & Shek, 1994).
6.	The elderly should regularly perform suitable light-to-moderate intensity exercises for endurance, strength, balance, and flexibility (Buchman, Boyle, Yu Shah, Wilson & Bennett, 2012; Seguin & Nelson, 2003).
7.	Indoor physical activity should be preferred for those with hay fever (Jayawardena, Sooriyaarachchi, Chourdakis, Jeewandara & Ranasinghe, 2020).
8.	Physical activity (outdoors in compliance with physical distancing) is widely encouraged to battle the psychological effects of prolonged self-isolation (Jiménez-Pavón, Carbonell-Baeza & Lavie, 2020; Brooks et al., 2020).
9.	Any physical activity with the potential to transmit viruses such as SARS-CoV-2 during the pandemic should be adapted or avoided (Ricci et al., 2020).
10.	Avoid risk-prone and vigorous physical activity (i.e., exercise training performed at 7-9 times the intensity of being at rest) during the pandemics to prevent additional burdens on the health-care system (Bøyum, 1996; Toresdahl & Asif, 2020).

Nutrition and diet-related interventions

While different researchers, health representatives, and advisors in nutrition science generally agree on the importance of the quality of diet for general health, enhanced immunity, cognitive ability, physical performance, and the prevention of various diseases (Rizkalla, Bellisle & Slama, 2002; Ventura et al., 2009), consensus regarding a proper nutritional strategy remains elusive (Aragon et al., 2017). Nutrition plays an important role in an individual's fitness, especially in relation to concepts such as metabolic flexibility, glycemic control, and cholesterol levels, all known to be either related to several aspects of immune function or to more severe cases of COVID-19 (Butler & Barrientos, 2020; Brufsky, 2020; Hu, Chen, Wu, He & Ye, 2020; Targher et al., 2020).

Except for some unbiased and strategic views of the topic, it remains difficult to identify a proper nutritional plan. While the "nutritional conundrum" results from over-reliance on statistical significance, omitting context, or biased views (e.g., as a result of financial interests), it is inherently impossible to prepare a universally-applicable nutritional plan. More recently, the debates on diet choice revolve around its environmental impact in addition to health benefits (Aboussaleh, Capone & El Bilali, 2017). Unhealthy diets are not only more common worldwide but also contribute to the development of chronic diseases (see, e.g., Echouffo-Tcheugui &

Ahima, 2019). Since severe cases of COVID-19 are widely present in individuals with obesity, chronic diseases, or poor medical condition (see, e.g., Cai et al., 2020; Muniyappa & Gubbi, 2020; Robilotti et al., 2020), healthy diets should be of top priority during the coronavirus pandemic (see, e.g., Butler & Barrientos, 2020; Yousfi, Bragazzi, Briki, Zmijewski & Chamari, 2020). Table 2 below demonstrates some of the diet-related interventions with the potential to aid in fighting the coronavirus pandemic.

Table 2. Excerpts of relevant diet-related interventions for peri-COVID-19.

1.	Dietary adherence is a critical success factor for diet-related interventions and should be considered when adopting a nutritional plan (Gibson & Sainsbury, 2017; Greenland, 2019).
2.	Diet should promote lean-mass gain or weight loss (if applicable) to help individuals reach their desired body mass index (Kwok et al., 2020; Sattar et al., 2020).
3.	Nutritional plans primarily focused on weight loss should be driven by caloric surplus, whereas the plans aimed at lean-mass gain should focus on caloric surplus (Aragon et al., 2017; Strasser, Spreitzer & Haber, 2007)
4.	Various nutritional plans can promote health benefits and body composition if calorie intake, macronutrients, and micronutrients are properly managed (Aragon et al., 2017; Lange & Nakamura, 2020).
5.	Ensure glycemic control in infected patients or individuals with chronic diseases such as diabetes (Brufsky, 2020; Bode et al., 2020).
6.	In stressful and tedious situations, such as quarantine, choose food that promotes a desirable stress response (Muscogiuri, Barrea, Savastano & Colao, 2020; Yilmaz & Gökmen, 2020).
7.	Controversy remains regarding different and/or ideal nutritional strategies for enhancing immunity (Hoyles & Vulevic, 2008; Pae, Meydani & Wu, 2012)
8.	Healthy diet is widely encouraged to aid the fight against COVID-19 (Khoramipour et al., 2020; Calder, Carr, Gombart & Eggersdorfer, 2020)
9.	Avoid diets low in essential nutrients to prevent the development of chronic diseases and a subsequent increase in susceptibility to and severity of COVID-19 (Butler & Barrientos, 2020; Mattioli, Sciomer, Cocchi, Maffei & Gallina, 2020).
10.	To reap the benefits of diet-related interventions, additional lifestyle changes should be considered in a comprehensive approach (Fechner et al., 2020; Willett et al., 2006).

The concept of metabolic (in)flexibility has long been propagated by researchers for obesity and type 2 diabetes (Goodpaster & Sparks, 2017). Preventing "metabolic disease" (e.g.,

disorders disrupting normal metabolism) requires interventions for improving metabolic flexibility in skeletal muscles and adipose tissue. A metabolically-flexible individual can adjust to fuel selection and thus effectively utilize, transport, or store different available nutrients, primarily glucose and fatty acids (Smith, Soeters, Wüst & Houtkooper, 2018). Individuals improve metabolic flexibility by increasing physical activity and decreasing the amount of sedentary time (Rynders, Blanc, DeJong, Bessesen & Bergouignan, 2018), by adopting weight-loss diets (see, e.g., Coen et al., 2015), and interventions such as time-restricted feeding/intermittent fasting (Chaix, Zarrinpar, Miu & Panda, 2014).

When discussing controversial topics, such as cholesterol accumulation facilitating the human body's retaliation to infectious diseases (Ravnskov, 2003; Tall & Yvan-Charvet, 2015), it is important to determine whether such (or other) interventions have a positive "net effect" when considering the role of higher cholesterol levels' in the co-development of atherosclerosis and metabolic inflammation, for instance. Hence, the aforementioned diet-related considerations and the physical-activity guidelines establish the need for a proper and multi-faceted conceptual model of a peri-COVID-19 lifestyle.

DISCUSSION

Stage 1: Pre-disease

Although the pre-disease stage in general overlaps with normal conditions, pre-emptive measures are important to reduce susceptibility to and severity of COVID-19 during the pandemics. Physical activity may reduce inflammation by lowering M1 macrophages in visceral adipose tissue, decreasing the tissue's adipose volume. It promotes butyrate-producing members of the gut microbiota, contributes to the production of anti-inflammatory myokines, improves gut barrier functions, and decreases postprandial glycemic and lipidemic responses (Miles, Wilson & Yeoman, 2019)

Elevated levels of cardiorespiratory fitness and exercising at moderate to vigorous intensity can improve immune responses to vaccination, reduce chronic low-grade inflammation, and improve various immune markers in several diseases (da Silveira et al., 2020; Yıldızgören, 2020). Regular moderate to vigorous physical activity enhances immune function and reduces inflammation, and reduces the severity of infections. Moderate physical activity (i.e., exercise

training performed at 3-6 times the intensity of rest) can improve the common chronic conditions that increase the risk of severe COVID-19 (Fang, Wang, Tang & Selvin, 2020).

The nutritional plans of different cohorts of people probably differed remarkably in the pre-disease stage. From the standpoint of the sedentary population, we would suggest two interventions in the pre-disease stage. First, improve metabolic flexibility with, for instance, proper meal timing following the circadian rhythm (see, e.g., Ma et al., 2003; Moran-Ramos, Baez-Ruiz, Buijs & Escobar, 2016) and time-based distribution of a variety of macronutrients to increase the satiety effect (Smith-Ryan, Hirsch, Blue, Mock & Trexler, 2019).

Stage 2: Progression

As the spread of an infectious disease such as COVID-19 progresses, the appropriateness of vigorous and high-intensive exercise with its potential disadvantages for the immune function is questioned (Shephard & Shek, 1994). Among the negative implications of such exercise, the authors highlight impaired resistance of the immune system to acute infections. For individuals indirectly affected by COVID-19, legislation and its enforcement in the majority of countries prevented a range of indoor and outdoor sports activities, posing a threat to individuals' fitness levels (Jimenez-Pavon, Carbonell-Baeza & Lavie, 2020). Irrespective of physical-activity possibilities, we strongly advise quarantined individuals to minimize their sedentary time as much as possible, for instance, to prevent endothelial dysfunction (Kruse, Hughes, Benzo, Carr & Casey, 2018), among other reasons.

To counterbalance prolonged sedentary time (e.g., during the mandatory quarantine and/or remote work), we recommend any type of physical activity possible, considering the limitations during the pandemics and associated measures (Ricci et al., 2020). Furthermore, Prince, Saunders, Gresty, and Reid (2014) argue that increasing the duration of physical activity is a viable intervention to reduce sedentary time. Martin et al. (2015) emphasize the importance of "goal setting and self-monitoring" when individuals intend to reduce sedentary time and increase physical activity. For remote work, standing workstations (activity-permissive workstations) represent a promising solution to reduce sedentary time, while children can benefit from reducing screen time (Altenburg, Kist-van Holthe & Chinapaw, 2016; Neuhaus et al., 2014)

Healthy individuals can embark on exercise routines (moderate steady-state aerobic exercise, less than 60 min) that (in comparison to being inactive) are believed to stimulate the ongoing exchange and redeployment of distinct, highly active immune cell subtypes in peripheral tissues

via circulation (Ranasinghe, Ozemek & Arena, 2020). Both aerobic exercise and resistance training are known to reinforce immune function, which could be depressed due to the unfavorable effects of quarantine (Balchin, Linde, Blackhurst, Rauch & Schönbächler, 2016; Khoramipour et al., 2020). An aggregate number of up to 5-6 sessions of aerobic exercise and resistance training is suggested, while the individuals with triggered respiratory tract infection should limit their activity to respiratory muscle training (Liaw et al., 2020).

Adding some amounts of physical activity during COVID-19 is particularly important for people with additional risk factors who should remain active to engage with the mental and physical consequences and severity of COVID-19 (Jiménez-Pavón, Carbonell-Baeza & Lavie, 2020). Moderate physical activity is one of the best stress management methods because it prevents psychological disorders as a result of anxiety and depression, for instance (see, e.g., Khoramipour et al., 2020). Stress and distress create imbalances of cortisol that negatively affect immune function and inflammation. Moderate physical activity also aids in bringing cortisol into balance (Hojman, 2017).

Infected individuals suffer from muscle loss due to prolonged inactivity (English & Paddon-Jones, 2010). These individuals could potentially benefit from consuming leucine (English et al., 2016), β-hydroxy-β-methyl butyrate (Deutz et al., 2013), or essential amino acids, all in the form of a supplement (Cheng et al., 2018). While adding supplements such as vitamins C and D, zinc, melatonin, and omega-3 fatty acids to a healthy diet should be done with caution, a growing body of knowledge demonstrates the potential of various supplements in aiding a fight against COVID-19 (Meltzer et al., 2020; Martineau & Forouhi, 2020; Shakoor et al., 2020; Reiter, Abreu-Gonzalez, Marik & Dominguez-Rodriguez, 2020). Vitamin C is known to boost the immune system and for its antiviral properties (Arvinte, Singh & Marik, 2020), while vitamin D and omega-3 fatty acids are also believed to aid the immune systems of infected individuals (Khoramipour et al., 2020). However, individuals should be informed about the potential benefits and/or side effects (Arvinte, Singh & Marik, 2020; Bae & Kim, 2020).

Among the mid-crisis diet-related interventions, limiting sugar intake or even adopting low-carbohydrate high-fat (LCHF) diets have been suggested to alleviate metabolic disorders and lower body-fat levels (Li, Liu, Liu & Li, 2020; World Health Organization, 2020). A recent paper published in Frontiers in Public Health (Maffetone & Laursen, 2020) sheds light on the role of an LCHF diet in "promoting a positive immune response against influenza virus infection." A growing body of evidence has further fueled the debate on the use of the LCHF

diet as a diet-related intervention, specifically the importance of high HDL and LDL cholesterol levels in battling infection (see, e.g., Fan et al., 2020; Schoenfeld, 2012). The sharp decrease in cholesterol levels is caused by impaired oxidation reactions (Fan et al., 2020).

The consumption of various fatty acids (e.g., from grass-fed butter, coconut oil, nuts, etc.) could maintain adequate levels and ratios of LDL and HDL cholesterol and reduce cardiovascular-disease risk; however, the research results remain inconclusive (Hayes, 2002; Forouhi et al., 2018). The most salient reason for adopting an LCHF diet during the progression stage lies in its ability to decrease remarkably the so-called respiratory quotient (RQ), which signals which macronutrients are being (primarily) metabolized on the cellular level. Relying primarily on fat for fuel generates less carbon dioxide (to oxygen consumed) and hence offers a viable intervention when the aim is to reduce the burden and time concerning artificial ventilation (Al-Saady, Blackmore & Bennett, 1989).

Stage 3: Recovery

While it remains difficult to avoid prolonged sedentary time and to increase physical inactivity to some extent in the progression stage, either due to confinement policies and/or infection itself, hazards such as physical inactivity should be addressed proactively in the recovery stage to off-set the inevitable negative corollaries, such as higher levels of adiposity (Qin et al., 2018).

Physical activity in the recovery phase is important for enhancing the components of physical fitness (muscular strength, cardiorespiratory fitness, coordination-agility). It is directly associated with the physiological functions of the primary bodily systems (circulatory, respiratory, muscular, nervous, and skeletal systems) and indirectly implicated in the proper functioning of other systems (immune, endocrine, digestive, or renal systems) (Fletcher et al., 2018; Lavie, Ozemek, Carbone, Katzmarzyk & Blair, 2019; Ozemek, Lavie & Rognmo, 2019). Importantly, individuals should be careful to gradually increase the duration and intensity before commencing with vigorous exercise. A possibility of other health-related issues exists when returning to vigorous exercise too soon before a full recovery after a respiratory tract infection (Hull, Loosemore & Schwellnus, 2020).

During the progression stage, individuals suffer from a reduction in various components of physical fitness; therefore, multicomponent training with aerobic, resistance, balance, coordination, and mobility-training exercises would be appropriate for senior adults (Jiménez-Pavón, Carbonell-Baeza & Lavie, 2020). In addition to the modalities of the exercise program, the focus for everyone should be on workout frequency, volume, and intensity. By adjusting

these variables and performing new types of exercise, patients who have recovered but suffered muscle loss should adopt exercise training that promotes skeletal muscle hypertrophy (Damas, Libardi & Ugrinowitsch, 2018; Schoenfeld, 2012).

For individuals who want to regain lost lean mass during prolonged physical inactivity or hospitalization, a combination of carbohydrate- and protein-rich post-workout meals is recommended (Sousa, Teixeira & Soares, 2014). While the consumption of antioxidants and/or anti-inflammatory nutrients is desirable (Sousa, Teixeira & Soares, 2014), the research on consuming those from nutritional supplements remains ambiguous but promising (Pastor & Tur, 2020). In addition, there are some concerns about antioxidants from nutritional supplements interfering with a natural pathway mechanism activated after a muscle-building training exercise. Due to its myoprotective ability, the promotion of muscle strength, and ability to facilitate glycogen resynthesis, we also suggest the intermittent ingestion of creatine (e.g., doses of up to 20g for several days) (Roberts et al. , 2016). To further facilitate recovery (e.g., glycogen resynthesizes) after an exhaustive training exercise and ameliorate delayed-onset muscle soreness, the ingestion of approximately 3mg of caffeine/kg of body weight is suggested (Caldwell et al., 2017; Pedersen et al., 2008).

Ultimately, the diet-related interventions in the recovery stage should consider three focal points; first, the adopted diet should promote (long-term) adherence for an individual. Second, it should be tailored according to an individual's needs (e.g., contingent upon the somatotype and metabolic (in)flexibility) and goals (e.g., enhancing physical performance). Third, the targeted body composition can be achieved with a wide range of dietary approaches, primarily differing in caloric surplus (lean-mass gain) or deficit (weight-loss strategies). However, focusing on food choices that promote satiety and increasing the protein intake while increasing physical activity in the recovery stage are both widely recommended (Aragon et al., 2017). In addition to diet-related interventions and physical activity, regimes such as calorie restriction and time-restricted feeding show potential benefits for health-related markers, to prevent the development of chronic disease and to slow aging, and even to enhance physical performance (de Cabo & Mattson, 2019; Pons et al., 2018). In Table 3, we conceptualize these findings with a more nuanced view contingent on the aspect and stage of the peri-COVID-19 period. The conceptual model can be used to understand better or administer diet-related interventions and physical activity to various cohorts of individuals who aim to avoid sedentary behavior and engage in active lifestyles in different stages of pandemics.

Table 3. The conceptual model of physical activity and nutrition in peri-COVID-19.

Aspect/Stage	Pre-disease	Progression	Recovery
Physical activity	Improve metabolic flexibility and glycemic control (if applicable). Moderate-intensity and vigorous aerobic exercise and resistance training. Physical activity should target lean-mass gain or fat-mass loss.	Healthy individuals should practice moderate-intensity exercise of all types. Infected individuals should proceed with respiratory-muscles exercises. Individual workouts to be preferred to avoid virus transmission.	Gradually increase duration and intensity (of aerobic and resistance) training. Individuals recovering after the infection should regain lean mass and prioritize resistance training. Overweight individuals should design physical activity considering calorie-deficit nutritional plan.
Diet-related interventions	Improve metabolic flexibility and glycemic control (if applicable). Nutritional plan should promote reaching desired BMI. A range of nutritional plans will help individuals reach similar goals. The goal should be lean-mass gain or fat-mass loss.	The consumption of micronutrient-dense food should be preferred. Tailored interventions, such as low-carbohydrate diets, might be beneficial. Decrease the rate of lean-mass drop. Nutritional supplements exhibiting potential to aid.	Nutrient-dense and lean-mass-promoting food for severe cases of COVID-19 who suffered muscle loss. Weight-loss primarily driven by a calorie deficit for overweight individuals. Satiety effect of food and protein intake should be acknowledged in designing one's nutritional plan. Supplements can promote recovery.
Sedentary behavior	Reduction of sedentary time should be of key importance in all stages.		

CONCLUSION

The present study conceptualizes the peri-COVID-19 period and, drawing on a range of seminal papers and the vast majority of relevant recent research publications about physical activity and nutrition, provides context-specific recommendations for the inevitably increasing number of people with sedentary behavior during the coronavirus pandemic. Acknowledging controversy on various nutrition and sports science topics, we steer away from over-specifications to a more strategic view that demonstrates which guidelines and interventions should be prioritized and further tailored to one's specific needs. More importantly, we emphasize the need to adjust those guidelines and interventions with respect to individuals' conditions and stage of the peri-COVID-19 period.

Our main findings suggest the relative importance of physical activity, which should be moderate-to-vigorous before the infection, mitigated in intensity and duration during the

pandemic or even omitted when infected, and aimed at ameliorating the negative corollaries of quarantine interventions after "flattening the curve" and moving beyond the pandemics limitations in the recovery stage. Furthermore, in the pursuit of a nutritional strategy before, during, and after the coronavirus pandemic, our paper suggests considering diet-related interventions that focus on glycemic control, cholesterol levels, and metabolic (inflexibility) in every stage (Cucuzzella, 2020; Cucuzzella, Tondt, Dockter, Saslow & Wood, 2017), yet with varying degrees of relative importance. While metabolic flexibility should undoubtedly be achieved before the presence of an infectious disease, glycemic control, and increasing cholesterol levels tend to be of key concern during the pandemics itself and in the recovery stage (for patients, particularly). Finally, we briefly mention the promising aid of supplements; future research should thoroughly investigate the potentially beneficial role of supplements to fight COVID-19.

Declaration of Conflicting Interests

The authors declare that they have no conflict of interest.

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