Understanding the Potential Contribution of a Third “T” to FITT Exercise Prescription: The Case of Timing in Exercise for Obesity and Cardiometabolic Management in Children

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Title: Understanding the Potential Contribution of a Third “T” to FITT Exercise Prescription: The Case of Timing in Exercise for Obesity and Cardiometabolic Management in Children

Running Head: Timing of exercise in children

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Abstract

Currently, exercise prescription relies heavily on parameters included in the FITT principle: frequency, intensity, time (duration), and type of exercise. In this paper, the benefits of including timing (FITT+T), referring to when exercise is performed in relation to meal-time, is discussed. Current research indicates that timing is outcome specific. Total energy and lipid intakes, and post-prandial hypertriglyceridemia can be reduced when exercise is performed pre-meal, while glycemic control is improved with post-meal exercise. Although findings indicate that timing can aid in obesity management and cardiometabolic-risk reduction, most research involves adult subjects and acute investigations. Some research with children, concerning the effect of timing on appetite indicates that pre-meal exercise helps regulate energy balance, but also identifies key differences in response compared to adults. Overall, current findings support the benefits of timing, but research is required to establish guidelines that are specific to the pediatric population and their health-related goals, while incorporating other FITT components.

Keywords: Exercise; Timing; Obesity; FITT; Nutrition; Children
Introduction

Exercise prescription relies heavily on the parameters composing the FITT principle: frequency, intensity, time (duration), and type of exercise (Katch 1983). Recently, studies have begun exploring the benefits of adding a third T, representing the timing of exercise, to this principle (FITT+T). The term timing refers to when exercise is performed, in relation to a meal and/or the 24-hour period (e.g. morning vs. evening). Interestingly, incorporating timing into exercise prescription has the potential to improve cardiometabolic (Haxhi et al. 2013; Chacko 2016) and performance outcomes (Chtourou et al. 2011) without modifying other FITT parameters (i.e. improving outcomes without a greater time or effort commitment).

There is a growing body of literature supporting the importance of timing beyond its impact on performance driven outcomes such as differences in power output (Souissi et al. 2007) and fatigue (Chtourou et al. 2011) in response to exercise at various times of day (i.e. 24-hour period). However, this paper will address the timing of exercise in relation to a meal, as this area has a stronger association with energy balance (Albert et al. 2015) and cardiometabolic outcomes (Haxhi et al. 2013; Chacko 2016) that can be linked to morbidity and mortality. Moreover, this paper aims to demonstrate that children are underserved in the literature concerning this topic. Childhood represents an excellent period to introduce these training techniques as the prevention of obesity and the effective management of blood glucose and lipids at this age may influence healthy habits which may help to prevent negative cardiometabolic outcomes in adulthood.

Timing for Energy Balance
Research shows that both energy intake and expenditure play important roles in bodyweight regulation (Wiklund 2016). While it was once accepted that exercise caused an increase in energy intake as a compensatory measure (Mayer 1956), acute exercise is now known to reduce appetite sensations, energy intake, and promote a negative energy balance (Moore et al. 2004; Martins et al. 2007; King et al. 2011). A systematic review and meta-analysis completed by Thivel and colleagues found that an acute bout of aerobic exercise can reduce food intake in youth, with the most profound results being observed in those with obesity (Thivel et al. 2016). This anorexigenic effect of exercise represents a novel intervention technique, especially for youth with obesity who would stand to metabolically benefit the most from such an intervention.

In one of the first studies in this field, King et al. reported that hunger and energy intake were both reduced within 15-min after aerobic exercise in adults (King et al. 1994). This effect is however short-lived and appetite response returns to baseline within 30-90-min following exercise (Broom et al. 2009). Recently, timing, in the context of the anorexigenic effect of exercise, was specifically tested by comparing a bout of exercise immediately prior to meal consumption with a condition involving a 135-min sedentary period between the end of moderate-to-vigorous intensity aerobic exercise and meal initiation (Albert et al. 2015). This research, conducted with teenagers/young adult males, demonstrated that energy intake at lunch was 11% lower when exercise was performed right before the meal compared to the condition using a 135-min sedentary delay (Albert et al. 2015). This laboratory-based finding was replicated in young children (5.6 years old) in a school setting, where reductions in energy intake of 16% were documented when exercise immediately preceded meal vs. the resting condition (Mathieu et al. 2018). Both laboratory and school (real-world) settings demonstrated statistically
significant findings, with the school-based study showing a slightly smaller effect size (0.53 vs. 0.47). This difference may be the result of other extraneous variables that are present in the real-world environment that have not been replicated in laboratory experiments. This difference, although slight, may demonstrate the further need for real-world testing of timing before it can be considered for practical use. Moreover, timing appears to be important for improving the quality of the diet. Exercising for 30-min, immediately prior to a meal, can yield a 23% reduction in lipid intake as compared to ending the same exercise 135-min before meal (Albert et al. 2015).

A proposed mechanism for this anorexigenic effect involves acylated ghrelin (AG), mainly secreted by stomach cells (Kojima et al. 1999), which promotes appetite, meal initiation, and adiposity (Wren et al. 2001). A significant reduction of AG circulating levels is observed within minutes of initiating high-intensity exercise (Blundell et al. 2003; Broom et al. 2009) and reductions are paralleled with increased satiety close to the end of exercise (Blundell et al. 2003; Broom et al. 2009). Moreover, hunger sensations and plasma AG concentrations increase progressively during the post-exercise period (King et al. 1994) and promptly become similar to resting values (Broom et al. 2009), indicating the transient nature of the anorexigenic effect of exercise. Intensity and duration may be additional factors to consider in the effectiveness of timing. Higher intensity (Broom et al. 2009) and longer duration (Thivel et al. 2013) exercise may result in lower appetite sensations and energy intake for lean, overweight, and youth with obesity which suggests the need for a combined approach (FITT+T) to timing.

**Timing and Lipidemia**

Reducing post-prandial hypertriglyceridemia successfully limits the progression of atherogenic
changes in circulating lipoproteins, reducing the risk of cardiovascular disease (Katsanos et al. 2004). Although most do not suffer from the negative effects of these atherogenic changes until middle-age, the damage can begin as early as childhood, making reductions in post-prandial hypertriglyceridemia an important factor in reducing cardiovascular disease risk later in life (Hong 2010). In adults, post-meal exercise can have beneficial effects on the lipemic response to a high-fat meal (Katsanos and Moffatt 2004); however, research also indicates that exercise after a high-fat meal has no (Zhang et al. 1998), or equivalent to pre-meal exercise, (Katsanos and Moffatt 2004) lipid-lowering effects. A review by Haxhi et al. concluded that in adults, pre-meal exercise is more effective for lowering triglycerides and increasing HDL-cholesterol in the subsequent post-prandial state in individuals with hypertriglyceridemia (Haxhi et al. 2013), potentially due to higher adipose tissue lipolytic and total lipid oxidization compared with post-meal exercise (Enevoldsen et al. 2004; Bennard et al. 2006). Hypothesized mechanisms explaining this phenomenon include a decrease in very low density lipoprotein-triacylglycerol (VLDL-TG) after moderate-intensity exercise (Borsheim 1999) or that post-prandial exercise may acutely decrease the rate that chylomicron/VLDL-TG enter circulation (Katsanos and Moffatt 2004). Interestingly, post-prandial lipemia is reduced even when exercise is performed at very low intensity (30% VO2 max). Timing has a long-action period for lipidemia outcomes, with effects present when exercise is performed several hours prior to a meal (Aldred et al. 1994). To date, this effect has not been confirmed in youth. Establishing this effect in children and gathering evidence on the best time to exercise would provide a strong base for early cardiovascular disease prevention, a major killer among adults in North America (1 in every 4 deaths) (CDC 2017), that takes root in childhood where one-third are living with at least two-of-seven cardiometabolic risk factors, primarily when with obesity (Lambert et al. 2008).
**Timing for Glucose Homeostasis**

Prevention of post-meal hyperglycemia is important. A 14-year longitudinal study of individuals with type-2-diabetes showed that elevated blood glucose two-hours after meal consumption increases the risk for cardiovascular events by 50% and mortality by 89% (Cavalot et al. 2011). Poor glycemic control results in serious health issues including retinopathy, neuropathy, and cardiovascular disease (Rhodes et al. 2012). A favorable strategy for reducing post-prandial hyperglycemia is repeated muscle contraction-mediated glucose uptake through exercise (Borror et al. 2018) allowing glucose to exit the bloodstream and enter muscle tissue independent of insulin (Huang et al. 2007). In children, the prevalence of diabetes is rising (e.g. 3%/year for type-1-diabetes (Federation 2017)) and is associated with signs of microvascular and macrovascular complications, hypertension, dyslipidemia (Dean 2007; Pulgaron et al. 2014), and cardiovascular disease risk factors which can present as early as pre-adolescence in people with diabetes (Babar et al. 2011). In adults with type-2-diabetes, research indicates benefits from both pre-and post-meal exercise (Borer et al. 2009). Adult subjects with and without diabetes demonstrated that light (60-min) or moderate intensity (20–45-min) aerobic exercise starting 30-min post-meal can efficiently blunt hyperglycemia, with minimal risk of hypoglycemia (Chacko 2016). Currently, the daily physical activity of children with type-1-diabetes (Michaliszyn et al. 2010) is insufficient to achieve health benefits, increasing their risk of cardiovascular disease and emphasizing the need to promote physical activity in this population. Studies in adults have provided important physiological evidence, but it is now crucial to determine if the timing to promote post-prandial glycemic control for children is post-meal as it is in adults.
Perspectives Concerning a New “T” in Exercise Prescription with Children (FITT+T)

Timing in exercise prescription may generate health benefits, especially when optimized for age, sex, and health-status. Given the current knowledge concerning timing, the following points deserve attention in the literature.

Regarding energy balance, following a bout of aerobic exercise, energy intake is greater among women with excess bodyweight compared to normal-weight women (George et al. 2003). In young girls with obesity, there does not appear to be an effect of timing on acute aerobic exercise (Dodd et al. 2008). In adults, over several days of aerobic exercise, both men and women with excess adiposity demonstrate a better response than normal weight both men and women do through a slight reduction in energy intake (Durrant et al. 1982). Moreover, over six weeks, moderate-to-high-intensity aerobic exercise in the morning seems more effective than evening for appetite control, energy intake and weight loss in inactive overweight women (Alizadeh et al. 2017). From these preliminary findings concerning energy balance, timing, like other FITT parameters, will need to be studied targeting specific BMI classifications and sexes within pediatric populations, who are currently understudied.

Considering the rise in cardiometabolic risk factors and diabetes (Dabelea et al. 2014) in youth, the post-prandial lipid and glycemic lowering effects observed in adults requires further study in children. Given the health benefits associated with optimized timing and no additional time-commitment to training, timing in childhood represents an attainable prevention strategy for cardiometabolic disease. In adults, many studies investigating timing have examined individuals with type-2-diabetes. Unlike adults (2.6/1000 cases for type-1 and 3.4/1000 cases for type-2-
diabetes) (Menke et al. 2013), in children, the prevalence of type-1-diabetes greatly exceeds type 2 (1.93 vs. 0.46/1000 cases respectively) (Dabelea et al. 2014). These diseases (Type-1 and type-2-diabetes) differ in etiology and treatment (Cnop et al. 2005), and lipidemic profiles can deteriorate as well, it will be important to investigate if the post-prandial reductions in hyperglycemia and lipidemia seen in adults will be similar in children and what the best timing for both outcomes will be.

Lastly it will be necessary to verify that the acute positive health effects associated with timing can continue into adulthood if practiced chronically, improving health over the lifespan. A summary of findings related to the timing of exercise can be found in a supplementary file1.

**Future Directions concerning Timing with Children?**

In Canada, only 33% of youth accumulate ≥60-min of moderate-to-vigorous activity per day by weekly average (Colley et al. 2017), and at-risk populations, such as individuals with type-1-diabetes, are even less active (Maggio et al. 2010; Trigona et al. 2010). Considering that time is a primary barrier to exercise (Sallis and Hovell 1990), incorporating the concept of timing into exercise prescription may offer a more efficient strategy to reduce disease risk and help improve aspects related to obesity management that does not increase overall time requirements.

The majority of research concerning children and timing has been adapted using an adult model of exercise prescription and focuses on laboratory-style intervention techniques. However, children acquire the majority of their daily physical activity through unstructured play contrary

1 Supplementary Table S1
Timing of exercise in children to adults who engage in bouts of structured exercise. To be better adapted to children, researchers should investigate how timing can be applied to active play as well as through moderate-to-vigorous intensity exercise sessions. Furthermore, there is a lack of real-world, longitudinal studies concerning the application of timing in children. These longitudinal studies are crucial to determine if the acute effects of timing can lead to long-term health benefits and to determine a workable model for policy makers and exercise professionals to consider when assessing how timing can be successfully applied to the daily lives of children.

Encouraging results in children are present, but research must begin to focus on pediatrics and at-risk populations, using both acute and chronic investigations in laboratory and real-world settings while examining any potential sex differences. Long-term studies incorporating timing for children can bolster our understanding of this parameter in exercise prescription and may lead to changes in guidelines.

**Take Home Points:**

1. Timing exercise around meals shows promising results for energy-balance, post-prandial lipid, and glycemic control.

2. Research considering timing in exercise prescription for children shows promising results, but inconsistencies between sexes, bodyweights, and ages.

3. Longitudinal, real-world studies are required to determine optimal timing based on individual characteristics and outcomes.
Conflict of interest:

The authors have no conflicts of interest to report.

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References


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