HABITUAL PHYSICAL ACTIVITY AND HEART RATE VARIABILITY IN 12-YEAR OLD CHILDREN

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ABSTRACT

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The study of heart rate variability (HRV) provides useful information about the function of the cardiac autonomic nervous system. The effects of many environmental factors on HRV are well known, but the associations between physical activity (PA) and HRV, especially in children, are less investigated. Higher HRV is related to health and many pathologic conditions are associated with reduced HRV. Exercise causes HRV to diminish, but improves HRV in long term. PA promotes many health related changes in energy metabolism, aerobic fitness and body composition in children and adults. The recommended minimum level of PA in children is 60 minutes of moderate- to vigorous intensity activity per day. There have been promising results that a high level of daily PA has beneficial effects on resting HRV but also many controversial findings exist.

The aim of this study was to measure habitual PA and HRV in 12-year old children (n=28), and to investigate the relationship between the amount and intensity of PA, and, cardiac autonomic functions. Study population consisted of normal weight, Finnish boys and girls. PA and HRV were measured for three consecutive days. It was hypothesized that high PA level during the day would cause higher heart rate (HR) and less HRV the following night.

The result of the study was that there was no consistent, clear relationship between habitual PA and nocturnal HRV. However, a dose-response kind of relationship was observed between habitual PA and daytime HRV. There was a significant variation in HRV between the three days, but no significant differences between the nights. The associations between PA and HRV observed might be sporadic but give a hint about a possibly existing relationship. Future studies with more subjects and longer periods of measurements can perhaps clarify the association between PA and HRV in children.

Key words: Heart rate variability, habitual physical activity, heart rate, children, health.

CONTENTS

LIST OF ABBREVIATIONS

ANS = Autonomic nervous system

CANS = Cardiac autonomic nervous system

HF = High frequency

HR = Heart rate

HRV = Heart rate variability

LF = Low frequency

MVPA = Moderate to vigorous intensity physical activity

PA = Physical activity

RMSSD = Root mean square of sum of squares of differences in successive normal to normal intervals

VLF = Very low frequency

1 INTRODUCTION

Heart rate variability (HRV) is a recently developed, non-invasive method for the assessment of changes in heart dynamics caused by the autonomic nervous system (ANS). The method has shown great potential, as it provides valuable information about the function of the two branches of ANS on the myocardium. (Laitio et al. 2001.) In clinical settings HRV is used in investigations of several cardiological and non-cardiological diseases, such as myocardial infarction, diabetes neuropathy, arrhythmias and hypertension (Task Force 1999). In exercise sciences, HRV has been studied as a marker of athletic condition, recovery and overtraining (Aubert et al. 2003, Hynynen et al. 2010). In questions about public health, HRV has developed into a method by which stress and overload can be detected (Pichot et al. 2002, Rönkä et al. 2006, Saalasti 2003).

HRV refers to the interbeat intervals of heart rate (HR). Using either time domain or frequency domain methods, one can gather information about the length, distribution and number of these intervals. (Task Fore 1999.) HRV is a most individual phenomena (Iwasa et al. 2007, Laitio et al. 2001), but there are some common trends to be seen in different physiological conditions. HRV is, for example, affected by body composition (Nagai & Moritani 2004), time of day (Yeragani 1996), physical activity (PA) and exercise (Arai et al. 1989, Bernardi et al. 1998), gender and age (Pikkujämsä 1999, Laitio 2001, Galeev 2003). Most studies of HRV and physical activity have focused to the adult population and fewer studies about HRV in children can be found (Iwasa et al. 2007).

The growing number of obese children and adolescents is of concern worldwide. Many indicators of cardiovascular diseases are associated with obesity and overweight (Strong et al. 2005). Ways to prevent obesity and to promote health in the pediatric population are discussed a lot. PA is known to be a major factor affecting health and preventing the development of different risk factors for chronic diseases (Raitakari et al. 1997, Rowland & Saltin 2008). The recommended amount of daily PA for children and youth to promote health is at least 60 min at a moderate to vigorous intensity (Strong et al. 2005).

The aim of this study was to investigate the associations of daily PA on HRV in 12-year old children. The main interest was to see, if the volume and/or intensity of daily PA affects night and daytime HRV in children. It was assumed that the higher the level of PA is during the day, the higher would the sympathetic activity be the following night. From previous studies with adults, it is known that hard exercise or great amount of physical activity influences HRV and a shift in the sympatho-vagal balance of ANS can be seen (Hynynen et al. 2006, Pichot et al. 2002).

2 THE CARDIAC AUTONOMIC NERVOUS SYSTEM

2.1 Role and function

The sinoatrial node or the SA node is the pacemaker of the heart. It constitutes of specialized muscle tissue and depolarizes and repolarizes spontaneously providing thus the innate stimulus for the heart actions. From this node, the electrical impulse spreads throughout in the myocardium as follows: SA node (.00s) → Atria (.04s) → AV node (.04s) → bundle of His and Purkinje fibers (.15s) → Ventricles (.21s). If only this innate rhythm would affect the conduction of the heart, it would be beating steadily about 100 times per minute. (McArdle 2001, 326.)

It is the autonomic nervous system (ANS) that controls the fluctuations in the cardiac rhythm. Parasympathetic nerve endings, releasing acetylcholine, concentrate in the atria, SA node and AV node of the myocardium. Sympathetic nerve endings, secreting epinephrine and/or norepinephrine, end up in the SA node and AV node but also the muscles of the atria and ventricles (Figure 1). (McArdle 2001, 329-331.)

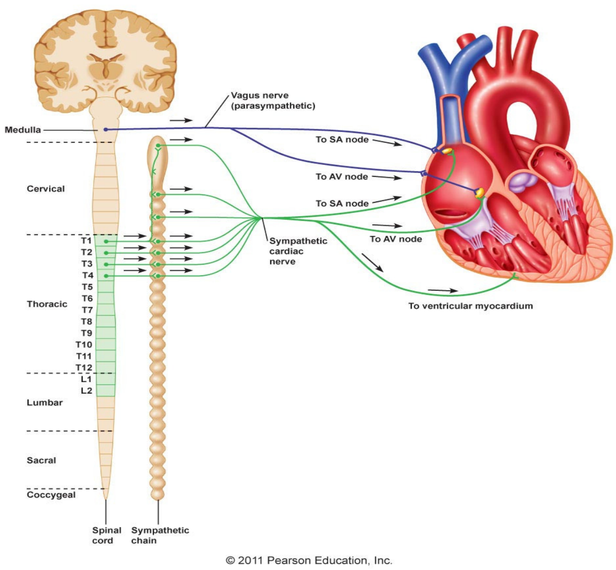

FIGURE 1. A picture of the autonomic nervous system and how it innervates the heart. (http://virtual.yosemite.cc.ca.us)

In healthy individuals, the role of ANS in beat-to-beat adjustments of the heart's rhythm and the function of the cardiovascular system is essential. With command from centers located in the brain stem, ANS branches send inputs to the myocardium. This causes modifications in cardiac output affecting blood pressure, which in turn adjusts the baroreceptor activity and sends feedback to the brain (Figure 2b). (Aubert et al. 2003.)

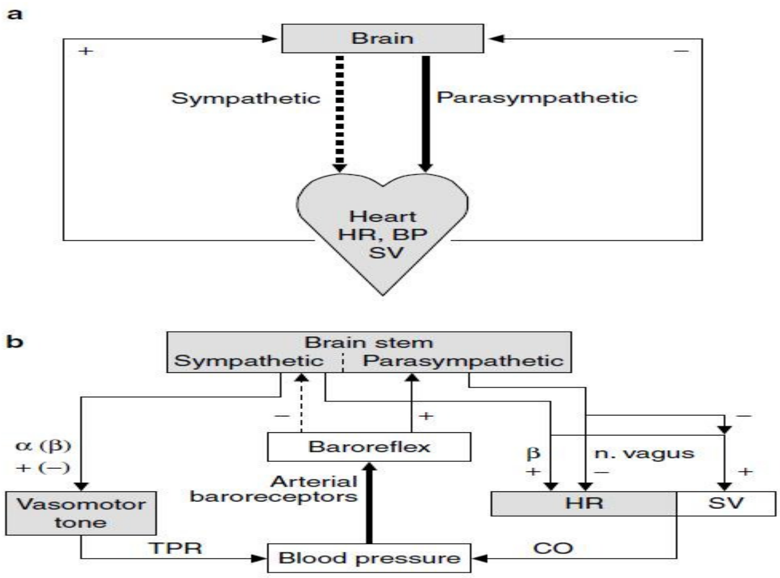

FIGURE 2. a) A simple illustration of the autonomic control of the heart. b) A more complex figure of the cardiovascular control mechanisms. (Aubert et al. 2003.)

Stimulation of sympathetic nerves has both a chronotropic and an inotropic effect on the myocardium. The chronotopic effect results in increased heart rate (HR) to over 100 beats / min, also referred to as tachycardia. The inotropic effect of the sympathetic nerves results in an increase of myocardial contractility. Whereas sympathetic nerves activate the heart, parasympathetic control causes bradycardia or retardation in HR via impulses to the sinus node. (McArdle 2001, 329-331.)

The two branches of ANS act reciprocally to adjust the body to environmental stimuli. With onset of exercise, central command from the motor cortex causes an inhibition of the parasympathetic nerves and simultaneously activation in sympathetic fibers. This causes a rapid change in HR immediately before and during exercise. Also emotional state can affect the cardiovascular response in the same manner. (McArdle 2001, 329-331.) Normal resting HR varies according to respiration. HR increases with inspiration and slows down with expiration. This kind of fluctuation is called respiratory sinus arrhythmia and is caused by the parasympathetic influence (Nienstedt et al. 1999, 193.)

3 HEART RATE VARIABILITY

3.1 Main principles of the method

The term Heart Rate Variability (HRV) has become the most used one, in order to describe the oscillation in the interval between consecutive heart beats as well as variations in instantaneous HR. The clinical significance of HRV has been known since the 1960's and the method has developed fast during the past years. Many new insights and the clinical importance of the method have been introduced. HRV is considered having great potential as a non-invasive method in adding valuable information about cardiac functions to physiological and pathological conditions. (Task Force 1996, Laitio et al. 2001.) The sinus node is altered by both time-varying neural and to a lesser degree mechanical input and this primarily causes HRV in vivo. As follows, it has been assumed that a smaller HRV reflects an abnormal autonomic sinus node activity characterized by a dominating sympathetic and reduced parasympathetic control. (Zaza & Lombardi, 2001.)

3.2 Different interpretation methods

3.2.1 Time domain methods

The time domain methods are perhaps the easiest way to interpret HRV. Applying these methods, HR at any point in time or adjacent QRS complexes resulting from the sinus node depolarization (normal to normal intervals), can be determined. Time domain methods are applied to a continuous ECG recording normally collected over a longer period such as 24-h. Either statistical or geometrical time domain measures can be chosen for analyzes. A list of different time domain methods can be found in table 1. The following four are the mostly recommended ones: standard deviation of the NN interval (SDNN); total number of NN intervals divided by the number of NN intervals in the modal bin (HRV triangular index); the standard deviation of the average NN interval (SDANN), and the square root of the mean squared interval differences of successive NN intervals (RMSSD). (Task Force 1996.)

TABLE 1. Selected time domain measures, their units and descriptions how to measure them. (Task Force 1996.)

Variable	Units	Description
		Statistical measures
SDNN	ms	Standard deviation of all NN intervals.
SDANN	ms	Standard deviation of the averages of NN intervals in all 5 min segments of the entire recording
RMSSD	ms	The square root of the mean of the sum of the squares of differences between adjacent NN intervals.
SDNN index	ms	Mean of the standard deviations of all NN intervals for all 5 min segments of the entire recording
SDSD	ms	Standard deviation of differences between adjacent NN intervals.
NN50 count		Number of pairs of adjacent NN intervals differing by more than 50 ms in the entire recording. Three variants are possible counting all such NN intervals pairs or only pairs in which the first or the second interval is longer.
pNN50	%	NN50 count divided by the total number of all NN intervals.
		Geometric measures
HRV triangular index		Total number of all NN intervals divided by the height of the histogram of all NN intervals measured on a discrete scale with bins of 7·8125 ms (1/128 s) (Details in Fig. 2)
TINN	ms	Baseline width of the minimum square difference triangular interpolation of the highest peak of the histogram of all NN intervals (Details in Fig. 2.)
Differential index	ms	Difference between the widths of the histogram of differences between adjacent NN intervals measured at selected heights (e.g. at the levels of 1000 and 10 000 samples)[21].
Logarithmic index		Coefficient φ of the negative exponential curve $k \cdot e^{-\varphi t}$ which is the best approximation of the histogram of absolute differences between adjacent NN intervals[22].

SDNN and pNN50 reflect the standard deviation of sinus cycle length. It has been shown that these HRV time domain parameters (SDNN and pNN50) are negatively correlated with HR. High values of vagal activity parameters (SDNN or similar) are normally associated with slow HR but the biological mechanisms underlying such an association has not been determined. (Zaza & Lombardi, 2001.)

Time domain measurements are vulnerable to artifact and may, therefore, not be the most accurate ones in physiological measurements. The repeatability of time domain methods is acceptable. Time domain methods are more sensitive than normal clinical tests to the function of the autonomic nervous system and provide thereby a good non-invasive tool for assessment of the function of the heart. They can be used with all lengths of recordings but, however, removal of artifact and ectopic beats is crucial before analyses. (Laitio et al. 2001.) It should be noticed that comparisons of time domain variables between measures based on different sources should not be made (Task Force 1996).

3.2.2 Frequency domain methods

For frequency domain measures, a tachogram is first made of the ECG recording. This tachogram is then analyzed with spectral analyses (Figure 3). The registration of ECG must be carefully edited. There must be at least 85% of original data left for each part of the recording to be analyzed. The stationary feature of ECG must be tried to be kept unchanged. In long term measurements the stationary is normally poor. Therefore, when using frequency domain methods, the recording is normally divided into 256 or 512 beat segments, from which linear trends are removed and data is filtered. (Laitio et al. 2001.)

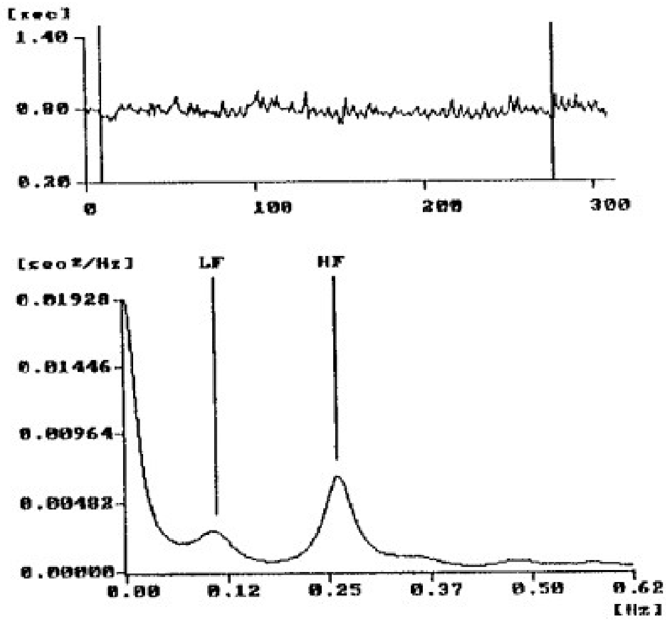

FIGURE 3. A tachogram (upper) and the corresponding power spectrum (lower) with LF and HF powers marked (Modified Villa et al. 2000).

Spectral analysis of HRV allows plotting the variance of the fluctuation in the HR signal as a function of its frequency and then computing the power in defined frequency regions. Spectral analysis can be made using Fast Fourier transform (FFT) or Autoregressive modeling (AM) or Wavelet decomposition (WT). (Aubert et al. 2003.) The FFT provides a simple approach, with a high processing speed, whilst AM has the advantage of presenting smoother spectral components, an easier post-processing of the spectrum and easier identification of the central frequency of each component. Using

AM, one can also easier do an accurate estimation of power spectral density even on a small number of samples on which the signal is supposed to maintain stationary. (Task Force 1996.) WT analysis is a relatively recent development, which is suited for non-stationary signals. It offers better time localization and resolution compared to FFT and AM and has potential to assess fractal characteristics in the signal. (Aubert et al. 2003.)

Frequency domain measures can manage to distinguish between sympathetic and parasympathetic activity and can also determine the amount of sympathovagal interaction to some extent. Different frequency domains show the activity of different parts of ANS. High frequency (HF) domain, between 0.15 and 0.40 Hz mostly describes the parasympathetic activity and sinus arrhythmia can clearly be seen. The low frequency domain (LF) between 0.04 and 0.15 Hz describes both sympathetic and parasympathetic activity. In lying position, LF is mainly affected by parasympathetic activity but in standing position also sympathetic activity can have some influence. The very low frequency (VLF) domain is between 0.0033 and 0.04 Hz and even though not yet fully proven, is thought to be influenced by the renin-angiotensin cycle, thermoregulation and vasomotor function of the body. (Laitio et al. 2001.) Also random habitual physical activity has been shown to influence VLF power (Bernardi et al. 1996).

Normally absolute values (ms^2) of VLF, LF and HF powers are reported. LF and HF powers can also be expressed in normalized units (n.u.), which describes the relative value of each power in comparison with total power minus VLF power. Normalized values should always be quoted with absolute values to describe the power distribution in total (Table 2). (Task Force 1996.)

TABLE 2. Variables of in the frequency domain method, units, description and the frequency range. (Task Force 1996)

Variable	Units	Description	Frequency range
		Analysis of short-term recordings (5 min)	
5 min total power	ms^2	The variance of NN intervals over the temporal segment	approximately ≤0·4 Hz
VLF	ms^2	Power in very low frequency range	≤0·04 Hz
LF	ms^2	Power in low frequency range	0·04–0·15 Hz
LF norm	n.u.	LF power in normalised units LF/(Total Power–VLF) × 100	
HF	ms^2	Power in high frequency range	0·15–0·4 Hz
HF norm	n.u.	HF power in normalised units HF/(Total Power–VLF) × 100	
LF/HF		Ratio LF [ms^2]/HF [ms^2]	
		Analysis of entire 24 h	
Total power	ms^2	Variance of all NN intervals	approximately ≤0·4 Hz
ULF	ms^2	Power in the ultra low frequency range	≤0·003 Hz
VLF	ms^2	Power in the very low frequency range	0·003–0·04 Hz
LF	ms^2	Power in the low frequency range	0·04–0·15 Hz
HF	ms^2	Power in the high frequency range	0·15–0·4 Hz
α		Slope of the linear interpolation of the spectrum in a log-log scale	approximately ≤0·04 Hz

HF variability is influenced mainly by the activation of receptors in the lungs and by commands from the central nervous system. HF variability of HR falls in the same rate as normal respiration (Laitio et al. 2001) and, therefore, HF variability decreases significantly with increasing respiratory rate (Pizalis et al. 1998).

3.2.3 Non-linear methods

HRV include non-linear phenomena, caused by complex interactions of hemodynamic, electrophysiological and humoral variables as well as the autonomic and central neural commands. (See figure 1, chapter 2.1.) Non-linear methods of studying HRV can provide a valuable tool for the physiological interpretation and for cardiovascular disease risk assessment. These methods are not yet fully standardized. (Task Force 1996.) Non-linear methods include attractors, 1/f behavior, fractal and correlation dimensions, Poincaré- and higher moment plots, approximate entropy, point wise correlation dimensions, detrended fluctuation analysis and Lyapunov exponents (Aubert et al. 2003).

Poincaré plots are constructed by plotting the RR-intervals in a xy-diagram, with the length of the previous RR-interval on the x-axis and the length of the following RR-interval on the y-axis (Figure 4). The shape of the area of all plots can be analyzed visually or by more complicated methods. The plots are examined for the standard deviation in short term (SD1) or long term (SD2) variation. SD1 is strongly correlated with HF power in frequency domain methods and describes mainly the parasympathetic activity. SD2 is correlated with LF power, and describes sympathetic activity. The SD1 / SD2 relationship describes the sympathovagal interaction. Data does not need to be as stationary as for spectral analyses in Poincaré plot analysis. (Laitio et al. 2001.)

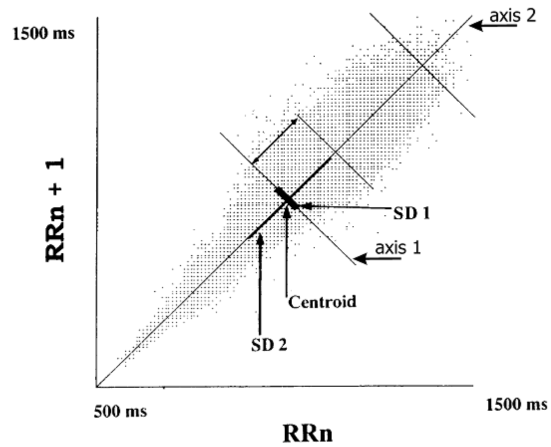

FIGURE 4. Poincaré plot for a healthy subject distinguished by the comet shape of the grey area (Modified Laitio et al. 2001).

The approximate entropy (ApEn) measures the complicity of a time series. For sporadic HRV, entropy is high and if HRV is regular, entropy is low. ApEn is calculated by forming different vectors of the time series of HRV. ApEn is <1, if the logarithmic probability of two data points in the HR series to be close to each other is big. If, on the contrary, the probability of two points to be close to each other is small, ApEn is ~2. (Laitio et al. 2001.)

Normal fractal HR dynamics include both very sporadic and very predictable actions. Detrended fluctuation analysis is used to measure the internal correlations of a time series of HRV. Fractal HRV includes both short term and long term correlations, which describes the sporadity and/or predictability of HRV. Short term correlations are caused by baro-reflex mechanisms, whereas long term correlations are due to mechanisms that try to keep HRV within some limits. (Laitio et al. 2001.)

3.3 Environmental factors affecting HRV in children

3.3.1 Body composition

It seems that there is an imbalance in cardiac autonomic function during early stages of obesity in childhood. This has been shown as there seems to be a reduced parasympathetic activity among healthy obese children and an elevated sympathovagal control (LF/HF ratio) in obese children compared with non-obese controls. (Fu et al. 2006, Paschoal et al. 2009, Martini et al. 2001, Gutin et al. 2001.) Nagai and Moritani (2004) have shown that obese children have smaller overall ANS activity as compared to their lean counterparts, especially LF variability of HRV. According to this study, the reductions have a relevance to body fatness, as total power was inversely correlated with percentage body fat in the particular study. This study further confirms that a reduced ANS function in healthy obese children might be a sign of later appearing cardiovascular and metabolic disorders. (Nagai & Moritani 2004.) Krishnan et al. (2009), on the other hand, have observed that FFM (fat free mass) predicts HR in girls. They observed a negative association between resting HR and FFM ($r= -.258$ $p= .015$).

3.3.2 Gender

Majority of HRV studies comparing genders, have shown that women have a predominance of vagal control measured as lower LF/HF ratio and men a predominance of sympathetic cardiac autonomic control expressed as LF power (Dart et al. 2002, Pikkujämsä 1999). Beckers et al. (2006) also confirmed this by observing a significantly larger proportion of LF power of HRV in men than in women. Surprisingly, it was also observed that women had a higher mean HR than men. (Beckers et al. 2006.) The menstrual cycle and hormonal factors are known to have an effect on HRV in women (Aubert et al. 2003, Pikkujämsä 1999). In children aged 11 to 15 years, there are differences in HRV parameters between genders. Median values of LF power for example are higher among girls at the age of 11-13-years, while it is greater in boys at the age of 14-15-years. Differences in HF power, and time domain variables were also seen but these differences disappeared at the age of 16-years. The authors conclude that gender differences in adolescents are most probably related to puberty and regulatory changes followed by puberty. (Galeev et al. 2002.)

Gender differences in HRV change with ageing and the difference between sexes diminish. For men, a clear decline in LF and HF power with ageing can be seen. Also other data on ANS function, in addition to HRV, suggest that there is a clear difference between genders in basal functions of ANS. The responsiveness of ANS to stressors is gender dependent, although differences can also depend much on the nature of stress. (Dart et al. 2002.)

3.3.3 Age

HRV is affected by age. Young children have smaller total variability than young adults (Pikkujämsä 1999, Galeev et al. 2002) and elderly have smaller total variability than adults. HRV is greatest at the age of 15 – 39 years. The fractal dynamics of HRV remains in all age categories. Entropy is diminished and long-term correlation changes with increasing age. (Laitio et al. 2001.)

Kirby and Kirby (1997) studied HRV in English 11-16 year old children. The authors observed that HRV is diminished with age already in the childhood. In another study, the LF/HF ratio of HRV was shown to decrease and parasympathetic control increase continuously after the 4th week of life in newborn infants. HF variability also increases after the 28th day of life. The changes seen in linear and non-linear measures of HRV after birth in newborns are a reflection of functional and anatomical changes in the cardiovascular system as well as maturation of ANS. (Mrowka et al. 1996.)

When comparing children (11.1 ± 2.1 years) and adults (35.4 ± 10.4 years) it was clearly seen how age affects spectral parameters of HRV. A significant inverse relationship between age and VLF, LF and HF powers was found. The LF/HF ratio increased in parallel with increasing age, reflecting thus an increase of sympathetic control or more likely a reduced parasympathetic control of HR with age. Also ultra-low frequency variation (ULF) was examined, but only a modest, although a significant relationship was observed between diminishing ULF power and increasing age. (Yeragani et al. 1996.)

In healthy 6-16-year-old children parameters reflecting total variation (SDNN and TF power) and parameters of parasympathetic activity (RMSSD, HF) were higher with higher age among the subjects. LF and LF/HF did not follow the same pattern. The age-related rise in HRV can describe an increased intensity of autonomic effects on HR in pre-pubertal years. At the age of 15-16, a stabilization of HR control takes place. (Galeev et al. 2002.)

3.3.4 Sleep

In healthy subjects, HRV is altered by sleep, so that parasympathetic influence on HR control increases during night-time (Pikkujämsä 1999). The stage of sleep also influences HRV. In REM sleep, the HF variability is diminished whilst sympathetic tonus increases. (Laitio et al. 2001.) In postnatal infants, LF/HF ratio, LF and total power of HRV, were all larger during active sleep compared with quiet sleep (Mrowka et al. 1996).

A clear wake/sleep-cycle variation in sympathetic and vagal tone exists even without any change in physical activity or posture. The LF/HF ratio is similar in both daytime and night-time awake periods, and a significant withdrawal of the HF component is to be seen in the morning at awakening. (Van De Borne et al. 1995.) Falling asleep has been shown to decrease LF power and increase HF power. Waking up in the morning has the opposite effect. (Yeragani et al. 1996.) Already in the childhood, HRV show a clear day-night variation, with increasing parasympathetic activity during night and a prevalence of sympathetic tone during the day. This may be related to the maturity of the “biological clock” and the organization of sleep. (Massin et al. 2000.)

4 PHYSICAL ACTIVITY IN CHILDREN

Physical activity (PA) refers to any movement of the body, caused by skeletal muscles that increase energy expenditure over the resting level (Bouchard & Shepard 1994, 77-88). Physical fitness in turn refers to attributes of people, related to the ability to perform PA. Exercise is a subcategory of leisure time activity, in which the aim is to maintain or improve one or more components of physical fitness. (Howley 2001.)

4.1 Health benefits

Health benefits of PA and fitness in youth include cardiovascular-, muscular- and metabolic fitness. (Ekelund et al. 2009, Jekal et al. 2009). The Toronto-model (Bouchard & Shepard, 1994, 77-88), simplified in figure 5, presents the close relationship between health, health related fitness and PA. According to this model, components of health related fitness are morphological, muscular, motor, cardiorespiratory and metabolic. PA affects health related fitness which in turn has an influence on overall health. These connections also act inversely. In addition genes and environmental factors also affect the three factors and their connections with each other. (Bouchard & Shepard 1994, 77-88.)

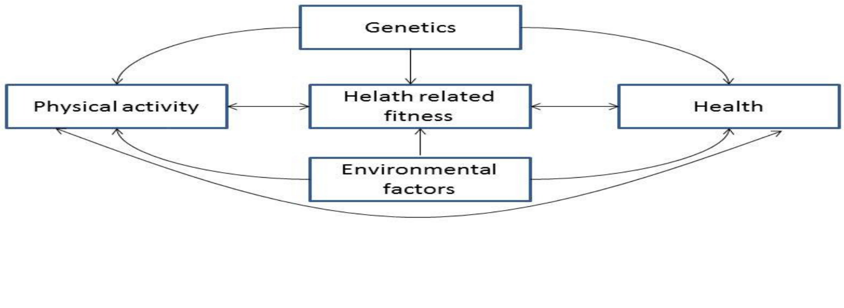

FIGURE 5. A simplified figure representing the Toronto model introduced by Bouchard & Shepard 1994, 77-88.

The accumulation of bone density, insulin resistance and obesity are, for example, life-long processes, starting at young age. Risk factors for cardiovascular- and metabolic diseases also start to develop already early in childhood. (Rowland & Saltin 2008.) Increased blood pressure, unfavorable blood lipid profile (Tolfrey & Batterham 1997), unfavorable blood glucose levels (Pirkola et al. 2008), overweight and fatness (Hussey et al. 2007), poor cardiorespiratory fitness and physical inactivity (Tammelin et al. 2007) have been reported in different populations of children. Raitakari et al. (1997) showed that PA has a favorable effect on many coronary heart disease (CHD) risk factors in youth. PA and cardiorespiratory fitness also have great beneficial influence on metabolic syndrome in children. An increase in daily moderate to vigorous intensity PA (MVPA) is clearly related with a significant reduction in the risk of metabolic syndrome. (Ekelund et al. 2009.) PA should be encouraged in early living years, in aims to reduce the development of risk factors for CHD and other diseases (Raitakari et al. 1997, Rowland & Saltin 2008, Jekal et al. 2009). The clustered risk for metabolic disease is known to be related to low levels of physical fitness in children (Froberg & Andersen 2005).

4.1.1 Body composition

A high level of PA is related to less adiposity in youth. Regular, at least moderate intensity PA has been reported to lead to a decrease in total body and visceral adiposity in overweight and obese youth. However, it seems that in normal weight children, the intensity and duration of PA needs to be higher in aims to reduce body fat. (Strong et al. 2005.) High level of PA was associated with lower body mass index (BMI) and thinner skin folds in males but only thinner skin folds in females. There was also a clear dose-relationship seen, which was consistent in all puberty stages. (Raitakari et al. 1997.) Aerobic fitness, determined by completed laps in the 20-m shuttle run test, had a strong negative correlation with body fatness in adolescent school-children (Boreham et al. 1997). Another study showed that in boys, body composition had an important effect on time spent in vigorous physical activity as had BMI on time spent in moderate activity. By this finding, and comparing with previous literature, the authors concluded that overweight boys seem to be less physically active than normal weight counterparts. (Hussey et al. 2007.)

4.1.2 Cardiorespiratory fitness

A low-to moderate dose response relationship has been reported to exist between PA and cardiorespiratory fitness (Strong et al. 2005). In the common European research project HELENA, adolescents with more than 60 min of MVPA every day, had significantly higher cardiorespiratory fitness than less active persons. Also moderate PA was found to be associated with better cardiorespiratory fitness. The amount of light PA had surprisingly also a positive effect on cardio-respiratory fitness in girls. (Martinez-Gomez et al. 2010.) The amount of self-reported PA was strongly related with aerobic fitness (20 m shuttle run test) in 12 and 15 year old boys and girls. The relationship remains, even after adjusting for body mass, height, body fatness and social class. (Boreham et al. 1997.) Adding physical education lessons into the schedule of pre-pubertal girls, aerobic fitness of the participants improved with 30 % during a 10 month period (Carlsson et al. 1997).

4.1.3 Neuromuscular system and bone

Habitual PA level is known to have a positive effect on upper body muscular strength in adolescents. Some studies with specific strength training programs have also shown improvements in muscular strength and -endurance without coupling to muscle hypertrophy. (Strong et al. 2005.)

Studies have confirmed a positive effect of exercise on bone density and its accrual in childhood (Rowland & Saltin 2008, McWhannell et al. 2008). Carlsson et al. (1997) have shown how a well-planned weight bearing exercise program was beneficial for bone mass development in pre-pubertal girls. Nine- to eleven-year- old girls took part in the study, which included 10 months of additional physical education three times a week for 30 min at a time. The subjects were divided into an activity group, taking part of this additional exercise and a control group having only the normal amount of physical education lessons. The activity group had more muscle strength improvement and they gained significantly more bone mass during the intervention period compared with the control group.

The positive effect of PA on bone mineral content in childhood is perceived into young adulthood. This was shown by Baxter-Jones et al. (2009) in their mixed longitudinal cohort study PBMAS. The group of active children had significantly greater mean adult bone mineral contents adjusted for height and weight than the group of inactive children. The active group had a greater bone mineral content (BMC) already in the childhood. (Baxter Jones et al. 2009.)

4.1.4 Metabolic fitness

PA has been shown to have a positive effect on blood glucose control so that more activity lowers the incidence of type 2 diabetes. Regular PA improves glucose metabolism via improved insulin sensitivity in muscle and liver. The improvements are not long lasting, thus PA has to be regular. (McArdle et al. 2001, 440-441.) A low level of vigorous PA and estimated aerobic power were significant predictors for insulin resistance in 12 year old youth. Aerobic fitness and PA did not, however, moderate the relationship between cytokines and insulin resistance. It was therefore concluded that exercise induced changes in cytokines and insulin resistance maybe independent from each other. (Rubin et al. 2009.)

Raitakari et al. (1997) observed significant dose-related effects of high PA level and blood lipid profile in Finnish young males. Compared with not active counterparts, physically active young men had significantly higher serum HDL-C levels and a tendency of lower total cholesterol and LDL-C levels. No such relationship was found in females. Furthermore, the same study showed a clear relationship between high levels of PA and lower serum total glucose level in both genders. Once again, only in males, high levels of PA were also related to lower serum insulin levels. (Raitakari et al. 1997.) There are controversial data on the response of physical activity on blood lipid profile in children (Froberg & Andersen 2005).

4.2 Recommendations

According to recommendations, school-aged children should involve in at least moderate intensity PA for at least 60 min/day. The activity should be developmentally appropriate, enjoyable and be varied with different types of activities. (Strong et al. 2005.) The HELENA-study concluded that reaching current recommended levels for the amount of daily PA in young people is associated with higher cardiorespiratory fitness in European youth. (Martinez-Gomez et al. 2010.)

Atkins (1997) has reported that the recommended 3x20 min moderate to vigorous daily PA was not attainable for the 9-10 year old children taking part in a longitudinal study with aims to determine the free-living patterns of PA and the differences in attainment of PA guidelines. Data indicate that periods of activity of shorter duration (5–10 min) were better fulfilled in the study population. During an average day the children in the study of Stone et al. (2009) accumulated seven times five minutes or more of moderate physical activity and remarkably less in vigorous or high activity. Ekelund et al. (2011) have recently shown that 30-40 % of adolescents worldwide are sufficiently active according to present recommendations.

In Finland, general recommendations of PA for 7 – 18 year old youth considering health benefits are as follows: all 7 – 18 year old persons should engage in for their age suitable PA at least one to two hours per day, and avoid both excess sitting and sedentary time. (Tammelin & Karvinen 2008.) In a study of Finnish 16-year old youth, Tammelin et al. (2007) have discovered that 23 % of boys and 10 % of girls reported to involve in MVPA a least 7 hours per week. Of the studied youth, 20 % reported to be physically active less than 1 h per week and 11 % and 9 % of boys and girls, respectively, were found not to take part in any kind of PA during the week. In a recent review of PA and fitness in the Finnish population, it was revealed that about 50 % of 12-14-year old children meet the recommendations for health related PA levels. According to the surveys, PA levels of Finnish school aged children have increased during the past 18 years. The study measured only leisure time PA. (Husu et al. 2011.)

4.3 Measuring physical activity in children

It is often problematic to assess the physical activity levels in children, because the patterns of activity are typically short, repetitive and non-sustained, burst like (Rowland & Saltin 2008). Objective measurements of physical activity (pedometer and accelerometer) have been shown to correlate well with energy expenditure, measured by doubly labeled water-method in young children. A subjective method (questionnaire) was also used, but found to correlate less with the doubly labeled water-method considered as the reference. (Ramirez-Marrero et al. 2005.)

4.3.1 Subjective methods

Self-reported information on PA in forms of questionnaires, interviews, activity diaries etc. are useful in investigating daily PA, but they do not come without limitations. The difficulty in recalling previous activity and relevant details such as time or duration may influence the result. The method used can be influenced by the age of the target group. It can be vice to have and adult to check a child's activity diary or questionnaire, although the child is supposed to complete the questionnaire as much as possible on his own. (Corder et al. 2008, Ekelund et al. 2011.) It has been shown that subjective methods of measuring PA are valid in different age groups of children from fifth grade upwards (Sallis et al. 1993). Interviewing is more valid than self-administered methods, but not always suitable for the study setting (Corder et al. 2008). The correlation between self-report methods and objective methods are reported to be moderate at best (Ekelund et al. 2011).

4.3.2 Objective tools

The daily physical activity of youth can be assessed using different data collecting device such as pedometers, accelerometers and HR monitors. The process involves many steps from collecting the data to data storage, post processing of data and adding of additional data such as age and anthropometric variables. This can influence the validity of the method. Pedometers are suggested to be used in large-scale studies, when the use of more advanced objective methods is for some reason limited and the main interest is to get a total volume of walking activity. (Corder et al. 2008.)

Accelerometers are an unobtrusive tool and easy to use. With accelerometers one can estimate the amount and intensity of physical activity. (Sirard et al. 2001.) Accelerometers are the most common way to measure free-living physical activity (Ekelund et al. 2011). When studying the daily physical activity of 8-10 year old boys with an accelerometer, it was found that 99 % of bouts of vigorous or high activity lasted 10s or less. The study proved that the use of high-frequency accelerometers in studying children should be emphasized since the activity bouts were 10 s or less. (Stone et al. 2009.) The use of accelerometers in analyzing physical activity requires the use of cut-off points for activity counts gathered. For Actigraph accelerometer, the cut-off points for sedentary time vary between 100-1100 counts/min and for moderate to vigorous time between 615-3600 counts/min. It has also been stated that the cut-off points would be age-related. For 12-year old children the moderate-time cut-off point is around 2000 counts/minute. (Ekelund et al. 2011.)

Graves et al. (2009) showed that the reliability of an accelerometer was similar regardless of the activity type i.e. intermittent compared to steady state exercise. The repeatability coefficient of variation (CV) was 9.1% for total intermittent and 8.7 % for total steady state activities. The bias was greatest with fastest speed both in intermittent and steady state activities.

The use of accelerometers in assessing physical activity in children has its weaknesses, for example, in children forgetting to wear the device, parents not agreeing on their children wearing an accelerometer and subject interfering. When analyzing data obtained from accelerometers, the use of cut-off points for different levels of activity can be discussed. (Corder et al. 2008.) All in all, accelerometers provide some calculation of activity which cannot be done with other methods (Hussey et al. 2007). Accelerometers with HR or temperature measurements in addition, have perhaps the best potential for accurate energy expenditure estimations of habitual physical activity in youth (Corder et al. 2008).

5 PHYSICAL ACTIVITY AND HEART RATE VARIABILITY

5.1 HRV during physical activity and exercise

Exercise is known to decrease HRV in normal subjects (Arai et al. 1989; Martinmäki et al. 2008). The effect of exercise is remarkable in both HF power and LF power of HRV. Both HF and LF power will diminish with onset of exercise in healthy subjects. This suggests a strong withdrawal of the parasympathetic activity of the cardiac autonomic activity during exercise (see figure 6). (Arai et al. 1989, Chen et al. 2008.)

In the study of Bernardi et al. (1996), an increased beat-to-beat variability paralleled with a decreased mean beat-to-beat interval in both random and rhythmic PA compared to rest. The authors claim that variations in PA are related to changes in HRV, especially increases in VLF. Changes in VLF power spectra were the greatest in fixed physical activity but also prominent in random PA. The duration of “ordinary” random activity fall within the range of VLF band (20-30 s to several minutes). With normal irregular daily activity, VLF band shows a broader distribution than with activity performed more rhythmically. This study shows that random activity is sufficient to cause increases in VLF power. The role of PA and its degree as a regulator of the lowest power spectrum should therefore be considered before assuming patho-physiological reasons for changes in HRV. (Bernardi et al. 1996.)

In the study of Kannankeril & Goldberger (2002) electrophysiology of the heart was measured during moderate exercise. It was found that the vagal activity of the heart was withdrawn but still measurable during moderate exercise. In normal resting conditions the activity of the parasympathetic nerves enhances sinus cycle length, AV block cycle length, AV interval and ventricular effective refractory period. This study showed that even though diminishing, there is still measurable parasympathetic activity in normal subjects during moderate intensity exercise. (Kannankeril & Goldberger 2002.)

HF power of HRV falls in the same rate as respiratory frequency (Nienstedt et al. 1999, 193). It has been shown that respiratory sinus arrhythmia measured as mean RR intervals and respiration-related components of the RR interval spectrum, diminishes when respiration rate increases (Pizalis et al. 1998). Arai et al. (1989) did not find respiratory sinus arrhythmia to interfere with HRV during exercise. They found a strong increase in respiratory rate and tidal volume, but at the same time a great decrease in HF power of HRV. Further analyses using HF power normalized with respiratory spectral power, confirmed the finding, that the cardiac vagal activity is strongly diminished during exercise.

5.2 HRV in recovery from exercise

During early recovery (1-2 min) after exercise, HRV is shown to increase rapidly and to decrease again during mid-recovery phase (4-5 min) (Figure 6). Approximately 9 min after stopping exercise, HRV is increased but has not reached pre-exercise levels in normal healthy subjects. (Arai et al. 1989.)

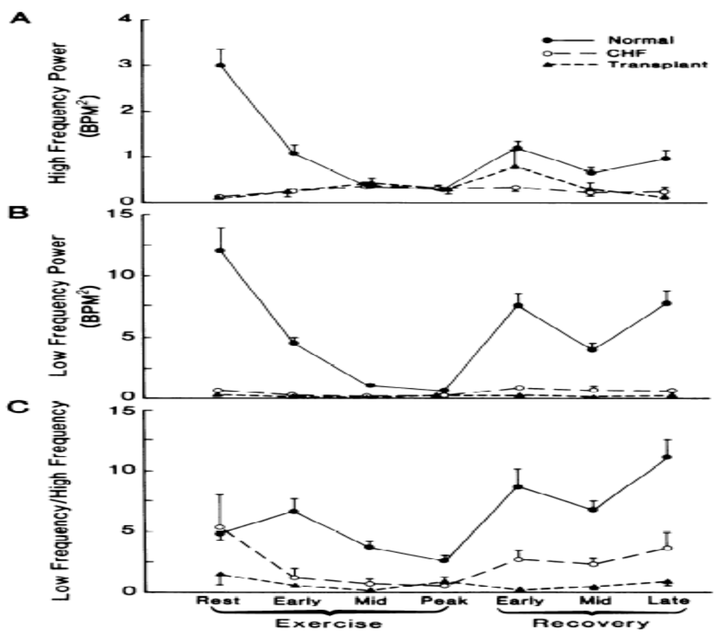

FIGURE 6. Frequency domain parameters of HRV measured before, during and after moderate intensity exercise in normal, chronic heart failure (CHF) and transplant patients. A) HF power at different measuring times. B) LF power at different measuring times. C) LF/HF ratio at different measuring times. (Arai et al. 1989.)

At early recovery, respiratory rate remains high and HF power increases, suggesting that respiration has a larger influence on heart rate regulation in early recovery from exercise (Arai et al. 1989). The first five minutes of recovery from exercise are distinguished by a shift from sympathetic to parasympathetic control. RR intervals increases significantly to the fifth minute of recovery compared to peak exercise condition. (Sundaram et al. 2009.)

In a study with 14 year old male football players, the function of ANS was evaluated during the night after a normal training day, a match day and a resting day. It was showed that the HF power and mean RR and pNN50 decreased significantly after a match but not after a normal training. The LF/HF ratio was 0.9 after the match day, when in normal conditions (after a resting day) it was only 0.6, suggesting a strongly altered ANS activity after a heavy physical load. (Bricout et al. 2010.)

Heavy PA for a period of three weeks was shown to reduce the nocturnal HRV and in particular the parasympathetic activity in French male employees. With a one week recovery period including less physical strain daytime, the men showed a rebound in parasympathetic activity of nocturnal HRV. (Pichot et al. 2002.) This study showed that physical stress affects cardiac autonomic nervous system function in a cumulative way. Hynynen et al. (2006) have suggested that HRV measured at morning awakening is sensitive to chronic athletic stress, and according to Brosschot et al. (2007) night time is the most important period for health, meaning that both physiological and psychological recovery happens during sleep.

5.3 Aerobic training, cardiorespiratory fitness and HRV

Exercise has been proven to be beneficial to improve autonomic balance and physical fitness in the general population. Especially, in younger subjects, exercise training studies show improvements in HRV indices (Figure 7). On the contrary, little or no changes are often found in studies with middle-aged or older subjects. (Aubert et al. 2003.)

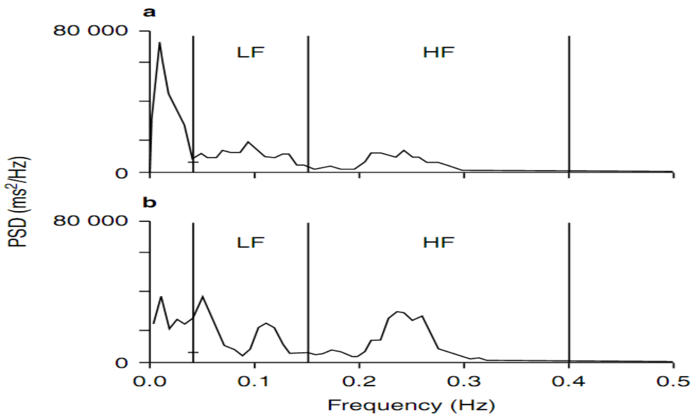

FIGURE 7. Spectral analysis of HRV in a sedentary young person a) before and b) after 6 months of aerobic training. (Modified Aubert et al. 2003.)

Based on a limited number of studies, it seems that in children, aerobic fitness rather than the level of PA influences HRV (Winsley 2002). In the study of Kirby & Kirby (1997), it was observed that the better the aerobic fitness (maximal VO_2) of the child, the higher HRV. This might be potential for reducing sudden cardiac death later in adult life. (Kirby & Kirby 1997).

The same kind of results was observed in adults by Kenney (1985). He discovered that a higher VO_2max corresponded to a leftward shift in the HR to respiratory sinus arrhythmia relationship. He concluded that there is a close relationship between aerobic power (VO_2max) and the vagal control of resting HR.

With a training period of 14 weeks, the aerobic power of participants increased, HRV increased and HR decreased at submaximal exercise intensities. The training had no effect on HRV at rest however. Lower HR measured at submaximal exercise levels after the training period, was probably due to higher vagal activity, as particularly the HF-power was increased compared to the pre-training measurement at these sub maximal levels. (Martinmäki et al. 2008.)

The effect of exercise training on HRV in children has not been studied much. Gamelin et al. (2008) studied how seven weeks of 3x 30 min running training affected HRV in 9.3 ± 1 year old children. The authors did not find any significant change in cardiovascular autonomic function after the training period. They thought that this could have been due to the relatively short training period. Nagai et al. (2004), on the other hand, found a 12 month exercise training program to be beneficial for improving both sympathetic and vagal HRV activities in school aged children. The program consisted of 20 min mild (HR 130-140 bpm) supervised training every day. This long-term exercise program improved the cardiac autonomic function of the children participating in the study.

5.4 Daily physical activity and HRV in children

Nagai & Moritani (2004) investigated the effect of daily PA and body composition on ANS function in children. The results showed that lean, physically active children had significantly lower resting HR than all other study groups (lean inactive, obese active, obese inactive). With regards to HRV, the study showed that higher PA level contributes to higher overall ANS activity in both lean and obese children. In both the lean and obese groups of children, physically active ones had significantly higher total power, expressed in normalized units (ln ms^2) than physically inactive ones. As discussed in the study, regular vigorous PA can influence ANS activity in a positive manner and thereby reduce the future risk of cardiovascular and metabolic diseases. (Nagai & Moritani, 2004.)

Krishnan et al. (2009) were interested in finding out the possible association between adiposity and ANS activity in children. The authors also measured daily physical activity, and the relationship between PA and HRV was reported. It was observed that in boys, resting HR and total amount of daily PA correlated negatively ($r = -.396$, $p < .001$) with the highest correlation found between the amount of high-intensity PA and resting HR ($r = -.379$, $p < .001$). It was also observed that increasing PA level was associated with increases in total HRV, but when adjusted for HR, these associations were not significant. (Krishnan et al. 2009.)

A significant negative correlation ($r = -.39$, $p < .05$) was observed between night time mean R-R intervals and the duration of intense physical activity during the perceiving day, in young children aged 7.5 ± 1.4 years. In contrast to previous studies (eg. Beckers et al. 2006), in this study parasympathetic activity at night was inhibited when physical activity load during the preceding day was high. The result suggests that prolonged intense exercise increases mean HR and decreases parasympathetic activity during the following night. (Iwasa et al. 2005.)

Because of great individual variation in HRV measures between the children, the authors took one girl into closer follow up for 12 consecutive days. In this case, it was found that HRV clearly forms a daily circadian rhythm and is influenced by both body activity and mental load (Figure 8). (Iwasa et al., 2005.)

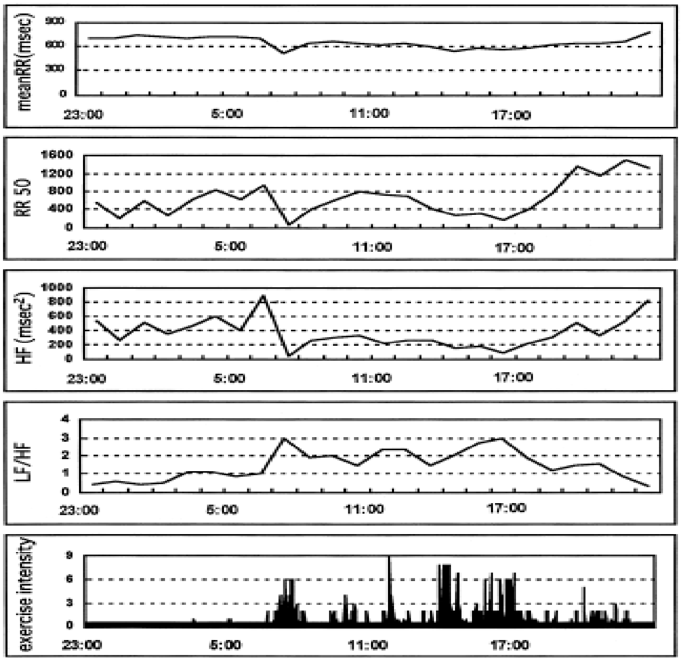

FIGURE 8. A 24-hour illustration of the HRV and physical activity of a single female subject in the study of Iwasa et al. 2005. (modified Iwasa et al. 2005)

6 PURPOSE OF THE STUDY

The purpose of the study was to investigate the effect of daily physical activity on HRV in 12-year old children. The study questions and hypothesis are as follows:

1. How does the overall level of daily PA relate to nocturnal HRV in children?
Hypothesis: The total amount of daily PA affects HRV during sleep so that more activity during the day causes less HRV during the night. Hynynen et al. (2006) observed that HF power, RMSSD and mean RR intervals decreased during sleep following a moderate or hard exercise days in males. A clear wake/sleep cycle variation in HRV can already be seen without changes in PA (Van De Borne et al. 1995.) In young boys, high levels of PA seemed to relate with lower resting HR (Krishnan et al. 2009).

2. Has the intensity of daily PA a relationship to nocturnal HRV in children?
-Does late evening activity affect night time sympathovagal balance?
Hypothesis: High intensity of exercise during the day affects night time HRV by reducing the overall variability and increasing sympathetic influence on HRV. In children, the amount of intensive PA has found to be inversely associated with meanRR-intervals during night, suggesting that prolonged intensive PA during the day increases nocturnal HR. When analyzing only one subject for twelve days, it was found that the amount of intense PA also had an inverse association with RR50 and HF-power, suggesting that with prolonged intensive exercise, the parasympathetic activity during night is decreased. (Iwasa et al. 2005.) Myllymäki et al. (2010) found that intense late-night PA resulted in a remarkable increase of stress reactions seen in HRV during the following night.

3. Does HRV differ significantly between different times of day?
Hypothesis: Yes, HRV is assumed to be different at different times of day with more sympathetic drive in the morning and more parasympathetic drive towards the night. HRV is known to follow a circadian pattern with increasing HF power distribution at

night and increasing LF/HF ratio and LF power in daytime (Van de Borne et al. 1995, Pikkujämsä 1999).

4. Has the level and/or intensity of PA any influence on daytime HRV?

Hypothesis: Yes, HRV is affected by PA so that it is decreased with onset and on-going activity, and it should therefore follow the variations in daily activity. PA is a strong regulator of HRV (Martinmäki et al. 2008, Arai et al. 1989). With increasing activity, a decrease in HF power but an increase in LF and VLF power can be seen. Random PA is enough to cause immediate changes in VLF power band. (Bernardi et al. 1996.)

5. Do body composition and/or daily PA have an influence on overall HRV in children?

Hypothesis: Yes. Both body composition and amount of daily PA do have an effect on total HRV. Nagai & Moritani (2004) showed that obese children had lower short-term ANS activity compared to lean ones. They further showed that higher physical activity leads to higher overall short-term ANS activity in both lean and obese children. In girls, fat-free mass was negatively correlated with resting HR (Krishnan et al. 2009).

7 METHODS

7.1 Subjects

The study included a sample of 30 5th-grade pupils from the public elementary school of Tikka in Jyväskylä. Demographics are presented in Table 3. Because of too much missing data for one subject and too outstanding values of physical activity for another one, the final number of subjects used in analyzes were 28. Pupils were selected for the study based on their own interest. One criterion for participating was commitment to the use of measurement devices during three consecutive days. On the other hand, participation was denied in case of chronic disease or medication that could hinder or affect bioimpedance or heart rate measurements. Written informed consent was obtained from each participant and their parent or legal guardian. The study design and protocol were reviewed and approved by the ethics committee of University of Jyväskylä.

TABLE 3. Demographics of the study population. Age (years), BM= total body mass (kg), Height (cm), BMI= body mass index (kg/m^2), fat %= body fat percentage, FFM= body fat free mass (kg), Min HR= lowest heart rate value during measurements (bpm), Max HR= Highest heart rate value during measurements (bpm).

	All (n=28)	Boys (n=8)	Girls (n=20)
Age (yr)	11.3 ± 0.5	10.3 ± 0.7	11.1 ± 0.3
BM (kg)	41.2 ± 9.3	38.7 ± 8.1	39.9 ± 9.8
Height (cm)	151.9 ± 6.7	137.3 ± 2.9	150.4 ± 7.5
BMI (kg/m^2)	17.7 ± 3.3	16.2 ± 3.2	17.5 ± 3.4
Fat%	17.6 ± 7.9	12.9 ± 7.5	19.0 ± 7.9
FFM (kg)	33.6 ± 5.6	32.6 ± 3.4	32.0 ± 5.9
Min HR (bpm)	57 ± 5	49 ± 4	58 ± 6
Max HR (bpm)	193 ± 10	169 ± 9	194 ± 10

Some background information about the children's and family's PA habits, leisure time activities and sleeping habits was collected with a questionnaire. The background questionnaire also contained questions about possible chronic medication of the child, special points to be considered in the measurements, eating patterns and the parents' attitude towards PA.

7.2 Study design

Figure 9 presents the current study design. Measurements lasted for four days, starting on a Tuesday morning. All preparations and controls were performed in the preliminary laboratory set up at the school. The 30 children participating in the project were divided into three measurement groups of ten persons per group, because of a limited number of equipment and personnel. Thus the measurements lasted for three weeks in February 2011.

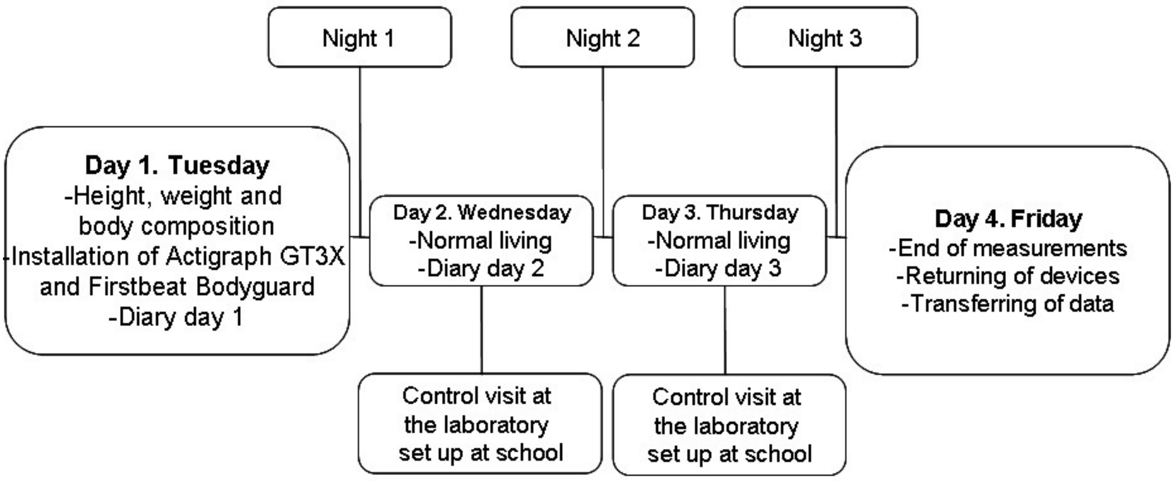

FIGURE 9. Illustration of the study design.

On the first day of measurements (see fig. 9), children were measured for anthropometrics and body composition. Children were also equipped with all the devices necessary for the coming measurements and a physical activity diary. This first visit lasted approximately 30 min. At this occasion, children were also instructed on the use of the different devices and the diary. Hereafter, children were allowed free living, with scheduled control visits to the laboratory every morning approximately at the same time as the first morning. On these control visits, children returned their diaries for the previous day and were given a new one for the following day. The functioning of all devices was checked and possible problems or misunderstandings of the protocol were corrected. On the fourth morning, i.e. Friday morning, children only visited the laboratory for returning the devices and receiving movie tickets for successfully completing the measurements.

7.3 Measurements

7.3.1 Anthropometric measurements

Body weight and body composition were measured using a bioimpedance device (InBody720, Seoul, Korea). Children were asked to go to the toilet before the measurement and they wore their underwear. Bioimpedance devices have been proven reliable, safe and most importantly rapid and easy to use in the acquisition of body composition in field settings, also in children (Salmi 2003, Jensky-Squires et al. 2008). The body composition measurement took place in the first morning of measurements when the child arrived to the preliminary laboratory set up. Children's height was measured to the closest 1 cm using a stadiometer.

7.3.2 Measurement of physical activity

Daily PA was measured at three consecutive days using Actigraph accelerometer GT3X, Pensacola, USA. The Actigraph was presented to the children at an earlier occasion when researchers visited the school for recruiting children to the project.

The first morning of the project, the child was equipped with all devices. The child was instructed on how to use the different devices and written instructions were also given. The aim of the project was that every child would use Actigraph three days at all waking hours. PA was not measured during night so the device was not used when sleeping. All devices were asked to be removed whenever entering water-activities such as, having sauna, shower, going to the swimming hall etc. Every morning when the child visited the laboratory setting room, he or she was asked about the previous day and instructed further, if necessary. Most children had already put on the accelerometer at home in the morning. In those cases, the time of putting on the device was asked and documented by the researchers. Children, whom had not put on the accelerometer at home, were helped to do so by the researchers. The last or fourth morning of the measurements, all devices were collected from the child and devices were emptied for data and prepared for the next weeks measurements.

Levels of physical activity were defined using cutoff points for the measured accelerations. The different levels were defined as counts / minute: Sedentary ≤ 100, Light 101-1999, Moderate 2000-5200, Vigorous 5201-35000, Very Vigorous > 35000. (Ekelund et al. 2011.) A sum of moderate to vigorous activity (MVPA) was calculated. Furthermore, PA data was split into morning, school and afternoon activities. These time periods were defined based on what the children had reported in the diary. Morning was regarded as the time before school start, school time was the length of the school day and afternoon was the time between end of school and bedtime in the evening. Evening time activity was also split into late-evening PA (>18hMVPA), which was defined as the amount of moderate to vigorous intensity physical activity after 18:00 o'clock until bedtime.

7.3.3 Physical activity diary

For each day of measurements a self-report diary was held. In the diary, the child had to fill in his or her doings in every 30 min periods during the day (See appendix 1). The diary was categorized for morning, school day and evening. There were suggestions for different types of activity such as resting, leisure time activities, physical education class etc. There were also some questions about the quality of sleep, time of going to bed and getting up in the morning, mood and length of school day. The diary was used for quantifying what type of activity there had been during the day and to know when the child had gone to bed and got up in the morning, and also for knowing the beginning and the end of the school day. The diary was a supplement to actual PA measurements.

7.3.4 HRV measurements

Firstbeat Bodyguard, Jyväskylä, Finland, was used for measuring HR and HRV in the study. Firstbeat Bodyguard is a wireless small device, that attaches to the thorax by two electrodes (see figure 10). Bodyguard collects heart beats (RR data) second-by second and allows continuous measurements of HRV up to 5-6 days. (Firstbeat.fi) Every child was equipped with a Firstbeat Bodyguard the first morning of measurements. Careful oral and written instructions on how to use the device were given. The Bodyguard was allowed to be removed only for shower or sauna or similar conditions. If the Bodyguard was removed, this should be marked in the diary together with time. In case of removing the Bodyguard, the electrodes were instructed to be changed and new electrodes were given to replace old ones.

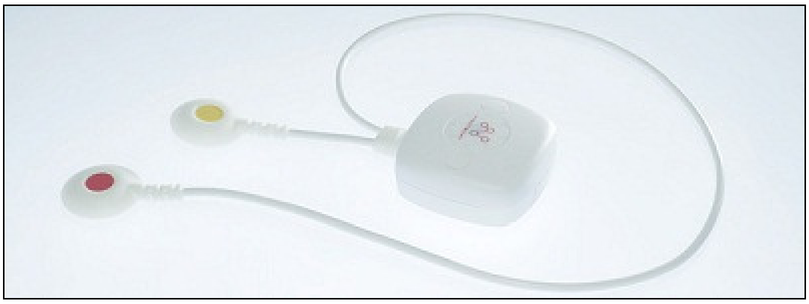

FIGURE 10. A Firstbeat Bodyguard which was used for HR measurements in the study. (http://www.firstbeat.fi)

RR data was collected over 72h. Using a Firstbeat –software (Firstbeat HEALTH), the measurement was extracted to digital form and then further analyzed by the software using Fast Fourier transform and neural network modeling (Saalasti 2003). For further analyzes of this study, the data was split into three days and three nights, based on the information about daily timetables found in the diaries. Furthermore, the daytime data was then split into similar parts as the physical activity data, i.e. morning, school time and afternoon, based on the same principles as for physical activity (see 7.3.2. Measurement of physical activity). Bodyguard measurements were analyzed using Firstbeat HEALTH- software and Microsoft Excel. All data was manually cleaned from artifacts, to contain as little bias as possible. All frequency domain variables were given by the software, but some time domain variables were calculated manually. In addition to the traditional frequency and time domain, HRV variables included also two Firstbeat's own variables which describe physiological states used. These variables were stress and relaxation indexes. These are calculated by the Firstbeat software using HR, HRV, heart beat derived respiration rate and neural network modeling (Saalasti 2003). The stress index describes a predominance of sympathetic tone and the relaxation index a predominance of vagal tone in the body (Firstbeat Technologies 2009).

7.4 Statistical analysis

All data was analyzed using Microsoft Excel 2003 and IBM SPSS 19.0 software. Tests of normality for both activity and HRV data were done using Kolmorogov-Smirnov´s test. Because of more normal distribution, Ln-corrected HRV variables were used in all further analyses. Variables of physical activity such as total active time, light, moderate, vigorous and MVPA, morning, school and afternoon and late-evening amounts of activity were correlated with HRV variables using Pearson's correlation analyses. Some linear regression analyses were done for further revealing the connections between activity parameters and HRV in which a significant correlation was found. Analyzes of variance of repeated measures was used for revealing significant differences between measurement times (for example night-day) and multivariate analysis of variance was used in case of comparing several groups. Level of significance was set at $p < 0.05$.

8 RESULTS

The subjects of this study represented normal weight, 12-year old, Finnish boys and girls. About 30-40 % of the children achieved recommended levels of physical activity, depending on the day. The average lengths of different parts of the children's days are presented below (Table 4). Days included school and leisure time but no supervised activities regarding the measurements. Thus all reported activity includes only habitual physical activities and school time activity.

TABLE 4. The average lengths of the different parts of participants' days.

	Morning	**School**	**Afternoon**	**Night**
Mean (h)	1,5	5,3	8	9.1
SD (min)	29	58	64	43

The measurements were completed well. There were a couple of subjects with missing HRV data for some parts of the measurements. Thus it was possible to have data for at least one night and one complete day for each included person. For activity measurements, the number of subjects with available data was 27 for the first day and 25 for the second and the third day. Means and standard deviations of average night time HRV and main PA variables are seen in tables 5 and 6.

TABLE 5. Mean and SD of average night time HRV.

	HR	**VLF**	**LF**	**HF**	**HF²**	**Stress**	**Relax**	**LF/HF**	**LF/HF²**	**Total power**	**RMSSD**
Mean	72	141	2372	3256	3852	95	80	85	72	5769	145
SD	6	68	1268	2089	2442	26	7	36	30	3280	196

TABLE 6. Variables of PA. Numbers refers to different days respectively. Tot. activity= the amount of active time including light, moderate and vigorous PA. Light= the amount of light PA time. MVPA= the amount of moderate- to vigorous PA for the day. School day= the amount of light- to vigorous PA during school hours. Afternoon= the amount of light- to vigorous PA during afternoon hours. >18H MVPA= the amount of late-evening moderate- to vigorous PA.

	Mean (min)	SD (min)
Tot.activity 1	299.0	65.3
Tot.activity 2	331.7	52.2
Tot.activity 3	316.6	65.7
Light 1	241.6	49.3
Light 2	272.0	52.4
Light 3	264.6	54.4
MVPA 1	57.4	33.7
MVPA 2	59.7	26.2
MVPA 3	51.9	25.4
Morning 1	28.9	16.8
Morning 2	32.4	18.1
Scool day 1	113.0	37.6
Scool day 2	120.6	33.2
Scool day 3	105.7	40.8
Afternoon 1	180.1	45.7
Afternoon 2	181.6	47.4
Afternoon 3	176.2	52.4
>18H MVPA 1	13.1	14.8
>18H MVPA 2	5.0	7.2
>18H MVPA 3	7.3	10.4

8.1 Physical activity

In PA, day one was significantly different from day two and three in several variables. Total activity was significantly lower in day one compared with day 2. The amount of light PA was significantly lower on the first day compared to the days two and three. Late-evening moderate to vigorous activity (>18HMVPA) was significantly highest in day one (Figure 11).

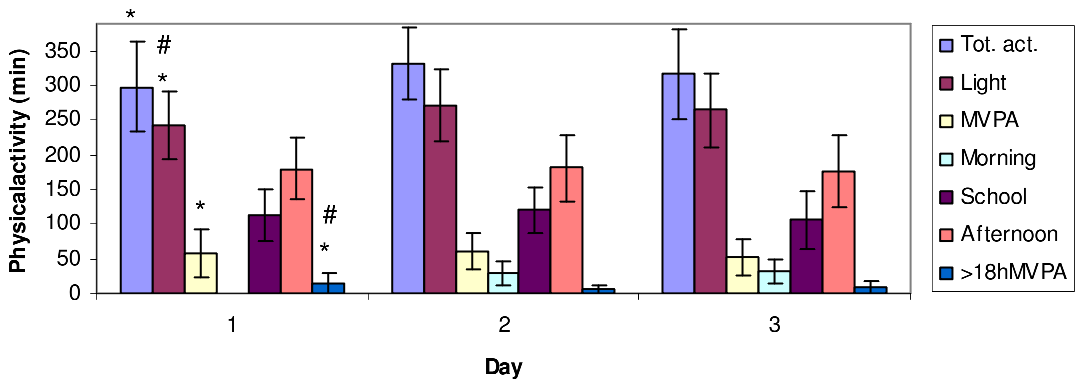

FIGURE 11. Physical activity levels during the three days of measurement. *= Significantly different from day 2 (p< .05) #= Significantly different from day 3 (p< .05).

8.2 HRV for average daytimes

When comparing HRV in the average of the three days, many significant differences between times-of-day were seen. Mean HR was significantly higher in the morning and significantly lower in the afternoon compared to school day. The mean HR in the afternoon was also significantly lower than in the morning (Figure 12).

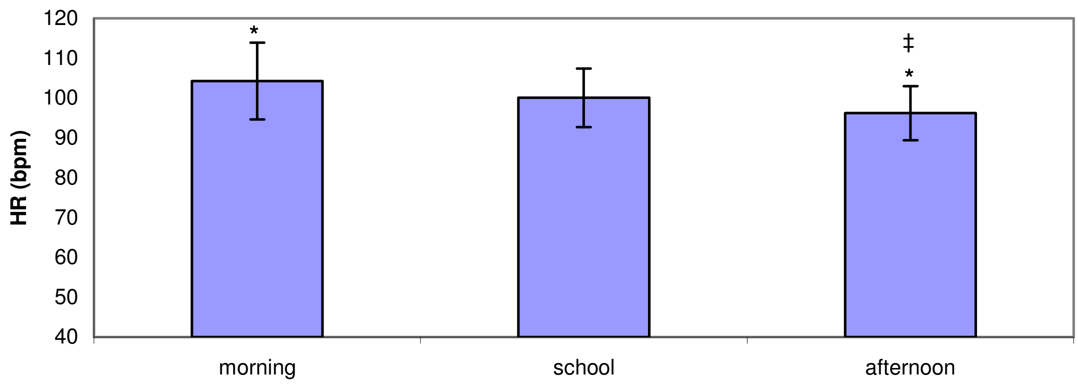

FIGURE 12. Mean HR during different times of day. * = Significantly different from school time (p< .05) ‡ = Significantly different from morning time (p< .001)

LnVLF was significantly lower in the afternoon than during the school day. LnLF was significantly lower in both the morning and afternoon compared to school time. LnHF and $\ln HF^2$ were significantly lower in the morning than during the school day, but significantly higher in the afternoon than in the morning. LnTotal power was significantly lower in the morning than during the school day (Figure 13).

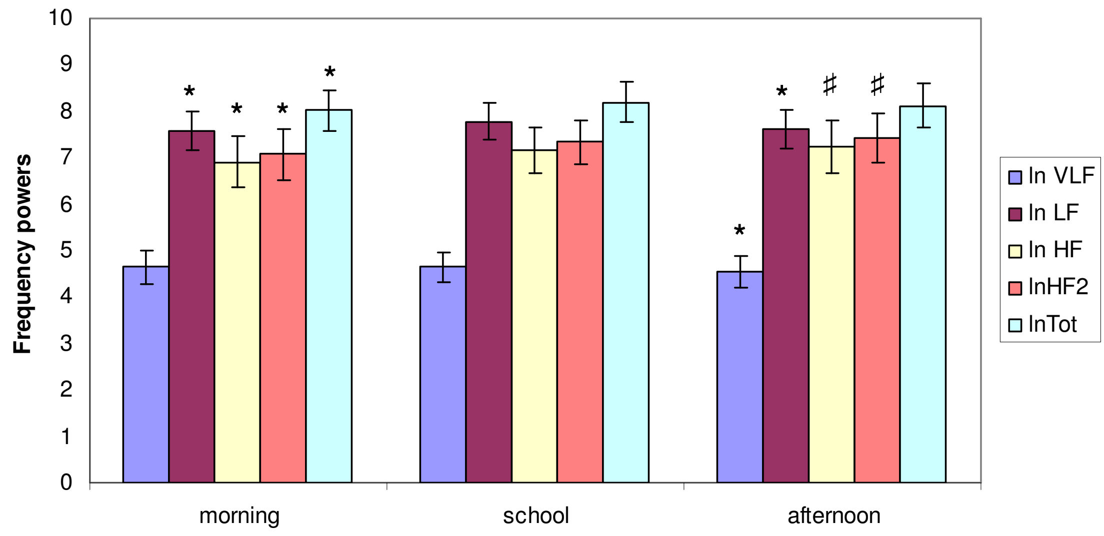

FIGURE 13. Different frequency powers during different times of day. # = Significantly different from morning time (p< .05) * = Significantly different from school time (p< .05)

LnLF/HF and lnLF/HF^2 were both very significantly lower in the afternoon than in the morning or during the school time. LnRMSSD was significantly lower in the morning than during the school day but was significantly higher in the afternoon respectively. LnRMSSD was also very significantly higher in the afternoon than in the morning (Figure 14).

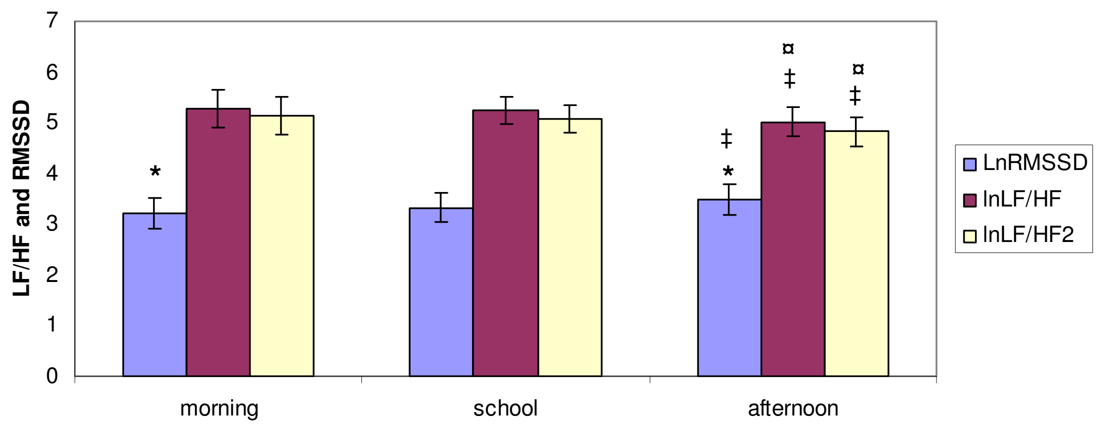

FIGURE 14. LF/HF powers and RMSSD during different times of day. ‡ = Significantly different from morning time (p< .001) * = Significantly different from school time (p< .05) ¤ = Significantly different from school time (p< .001)

LnStress was very significantly lower in both school and afternoon compared with morning time. LnRelaxation was significantly higher during school day and very significantly higher in the afternoon than in the morning (Figure 15). LF n.u. was significantly lower and HF n.u. very significantly higher in the afternoon than during school time. HF n.u. was also significantly higher in the afternoon compared to the morning (Figure 16).

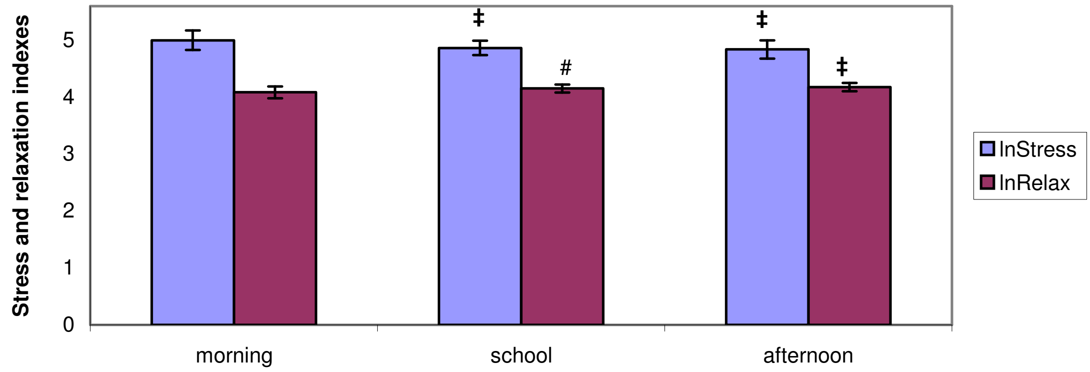

FIGURE 15. Stress and relaxation indexes during different times of day. # = Significantly different from morning time (p< .05) ‡ = Significantly different from morning time (p< .001)

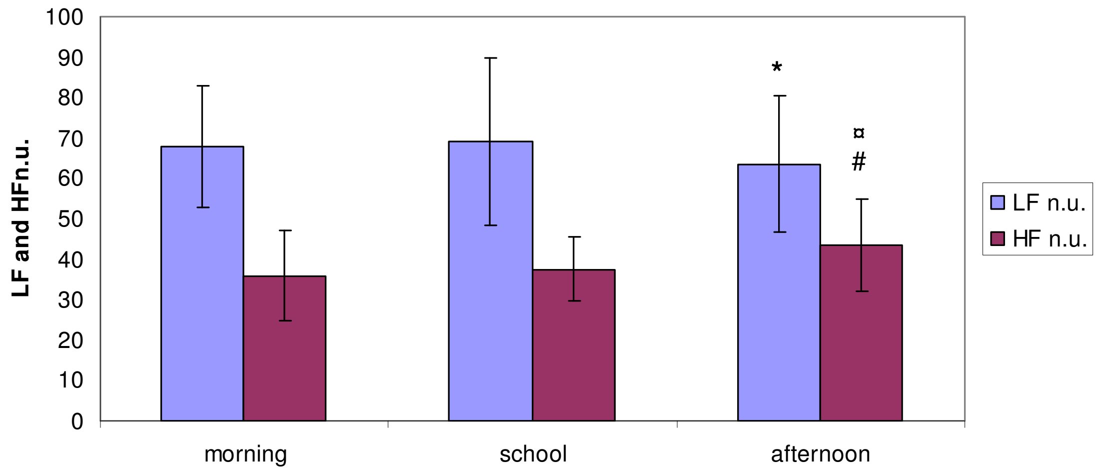

FIGURE 16. LF and HF normalized units during different times of day. # = Significantly different from morning time (p< .05) * = Significantly different from school time (p< .05) ¤ = Significantly different from school time (p< .001)

8.3 Day to day variation in HRV

There were no significant differences in HRV between the three nights measured. However, there were significant differences between daytime measurements in all HRV variables (Figures 17-29).

8.3.1 Mornings

Mean HR and lnStress were significantly lower in morning two than morning one (Figure 17 and Figure 19). LnHF, $lnHF^2$, lnRMSSD and lnRelaxation were all significantly higher in morning two than morning one (Figure 18 and Figure 19).

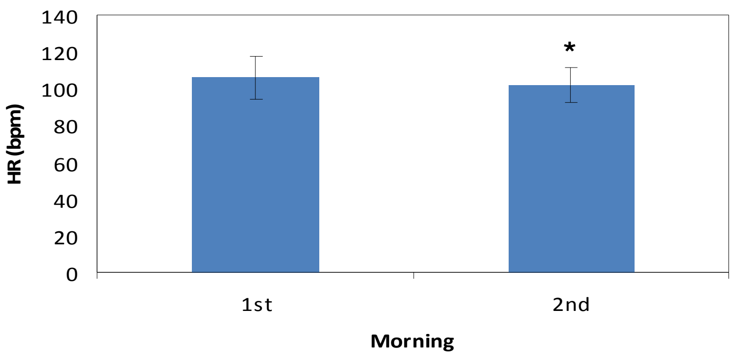

FIGURE 17. Mean HR during mornings one and two. *= Significantly different from Morning 1 (p< .05)

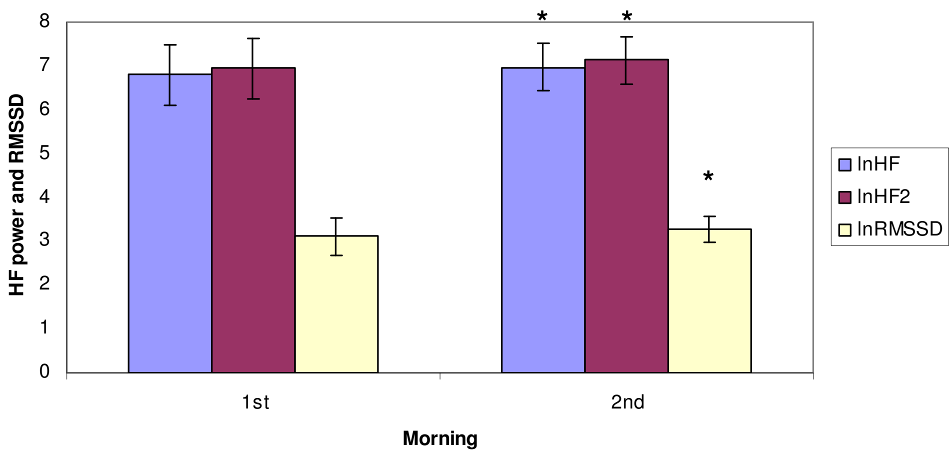

FIGURE 18. HF power and RMSSD during mornings one and two. *= Significantly different from Morning 1 (p< .05)

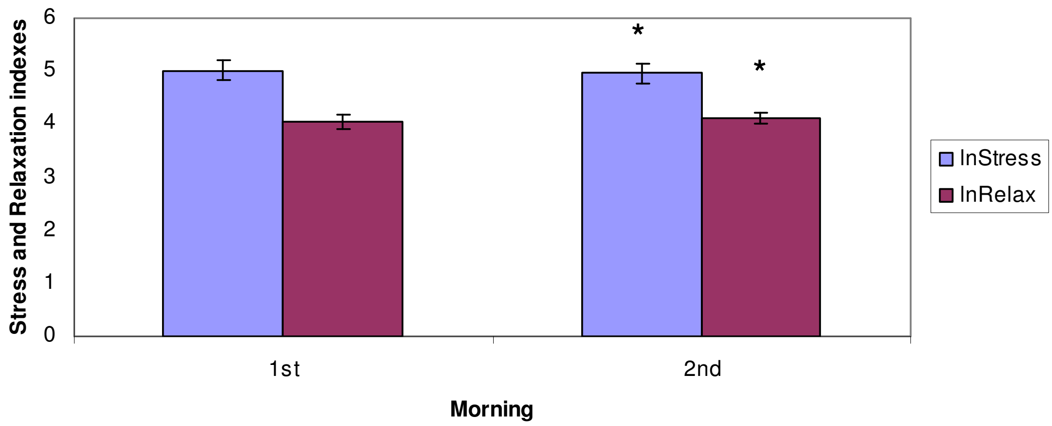

FIGURE 19. Stress and relaxation indexes during mornings one and two. *= Significantly different from Morning 1 (p< .05)

8.3.2 School days

Mean HR was significantly lower during school day three than school day two (Figure 20). LnRMSSD was significantly higher during school day three than school day one or two. LnLF/HF and lnLF/ HF^2 were significantly lower during day three compared with day two (Figure 21). All other frequency powers were significantly higher during school day three compared with school day one and two (Figure 22).

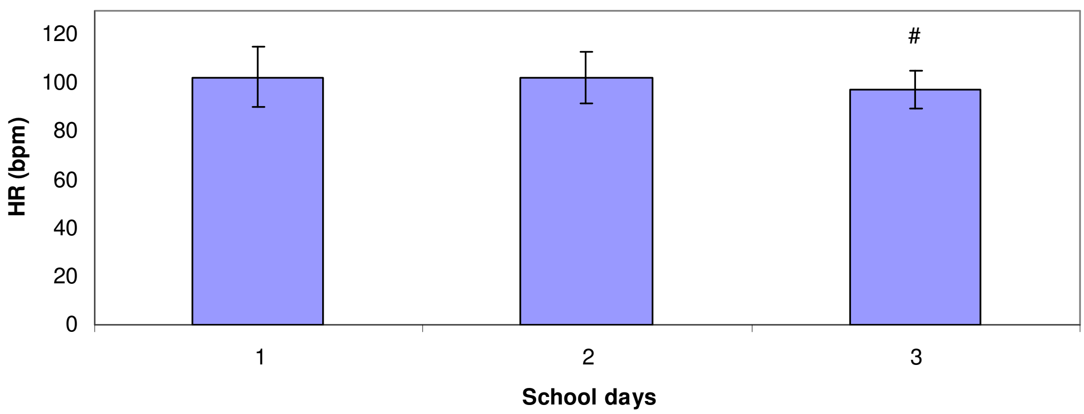

FIGURE 20. Mean HR during school days one, two and three. # = Significantly different from school day 2 (p< .05)

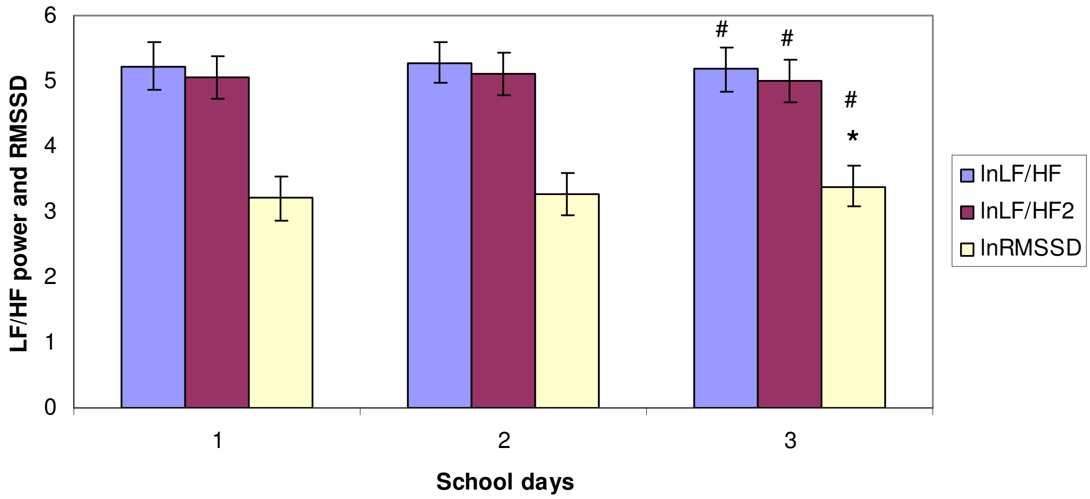

FIGURE 21. LF/HF powers and RMSSD during school days one, two and three. * = Significantly different from school day 1 (p< .05) # = Significantly different from school day 2 (p< .05)

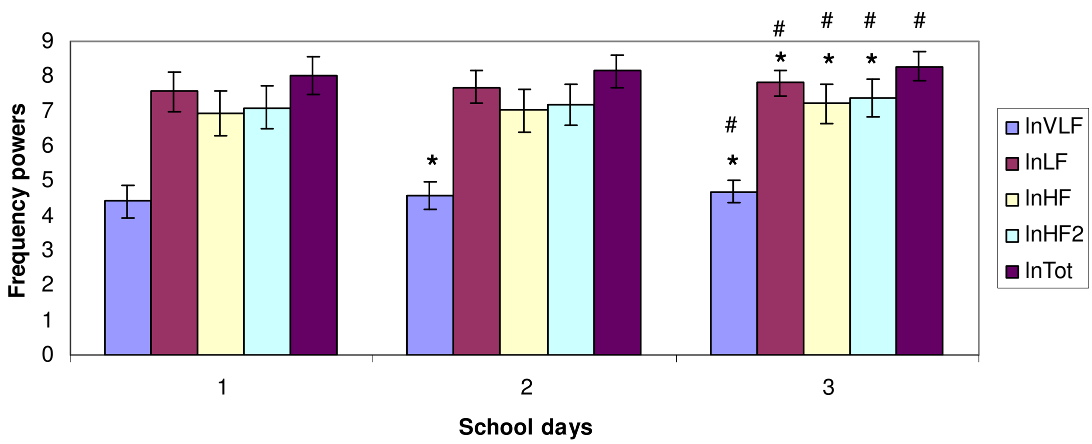

FIGURE 22. Different frequency powers during school days one, two and three. * = Significantly different from school day 1 (p< .05) # = Significantly different from school day 2 (p< .05)

LnRelaxation was significantly highest during school day three (Figure 23). LF n.u. was significantly lower and HF n.u. significantly higher during school day three compared with school day two (Figure 24).

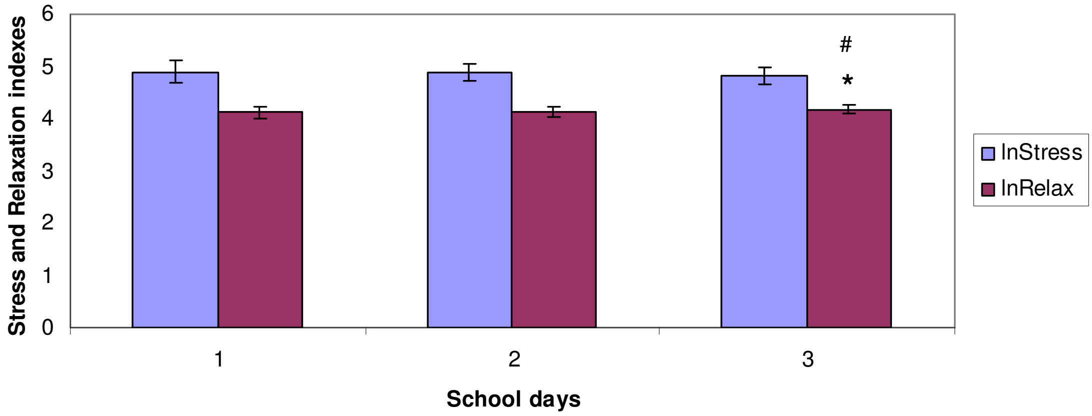

FIGURE 23. Stress and relaxation indexes during school days one, two and three. * = Significantly different from school day 1 (p< .05) # = Significantly different from school day 2 (p< .05)

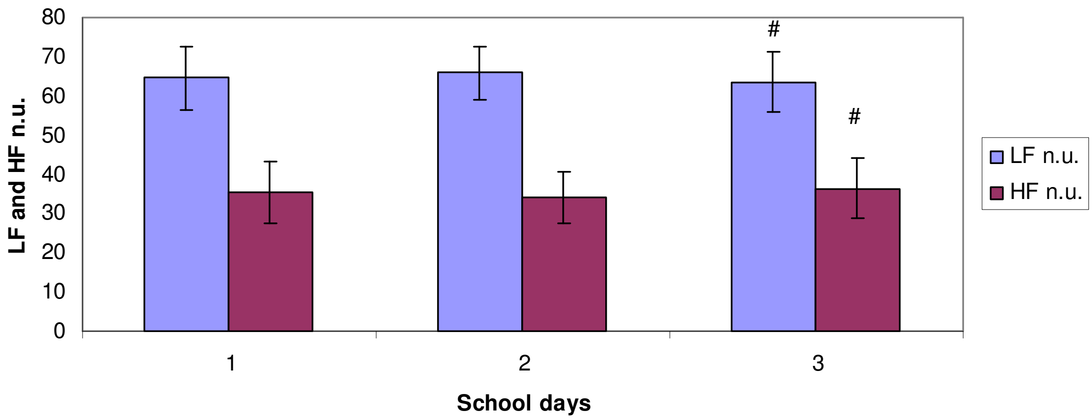

FIGURE 24. LF and HF normalized units during school days one, two and three. * = Significantly different from school day 1 (p< .05) # = Significantly different from school day 2 (p< .05)

8.3.3 Afternoons

Mean HR was significantly lower in both afternoon two and three compared to afternoon one (Figure 25). All frequency powers except lnVLF were significantly higher in afternoon two and three compared with afternoon one (Figure 26).

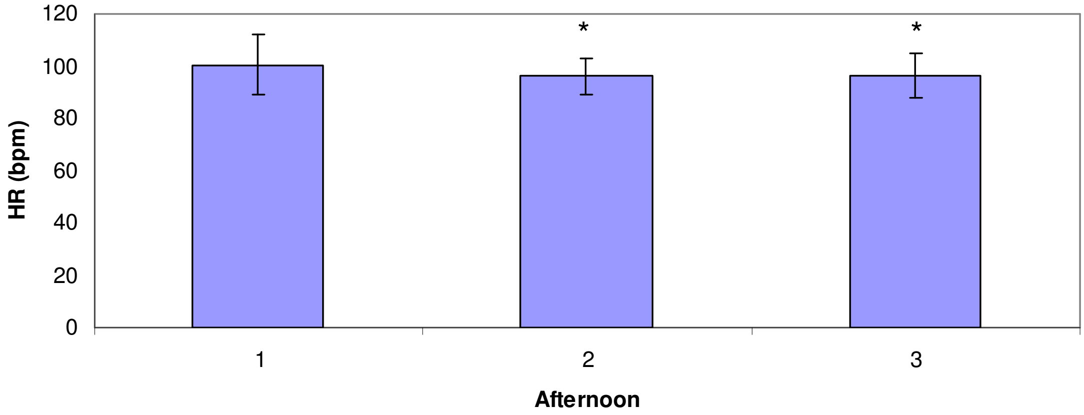

FIGURE 25. Mean HR during afternoons one, two and three. * = Significantly different from afternoon 1 (p< .05)

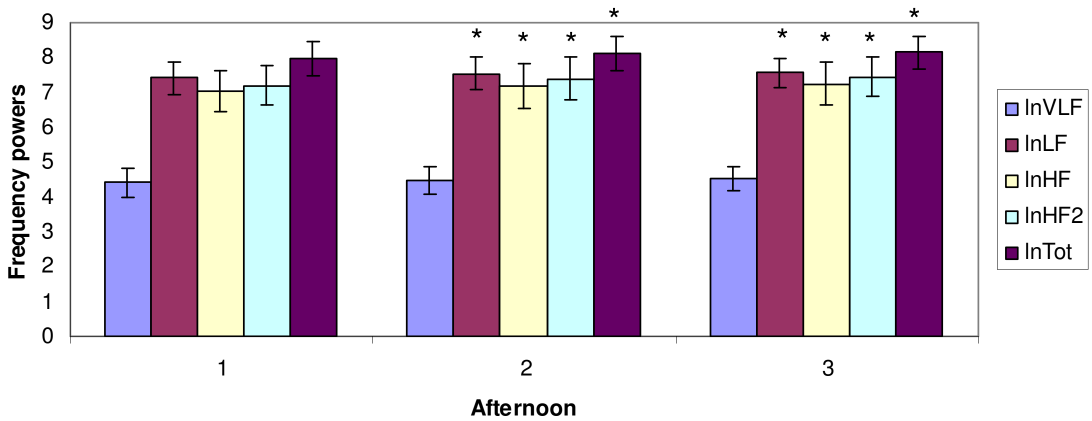

FIGURE 26. Different frequency powers during afternoons one, two and three. * = Significantly different from afternoon 1 (p< .05)

LnLF/HF and lnLF/ HF^2 were significantly lower in afternoon three compared with afternoon one. LnRMSSD, on the other hand, was significantly higher both in afternoon two and three than in afternoon one (Figure 27). LnRelaxation was significantly higher in afternoon two and three compared to afternoon one (Figure 28). LF n.u. was significantly higher and HF n.u. significantly lower in afternoon three than afternoon one (Figure 29).

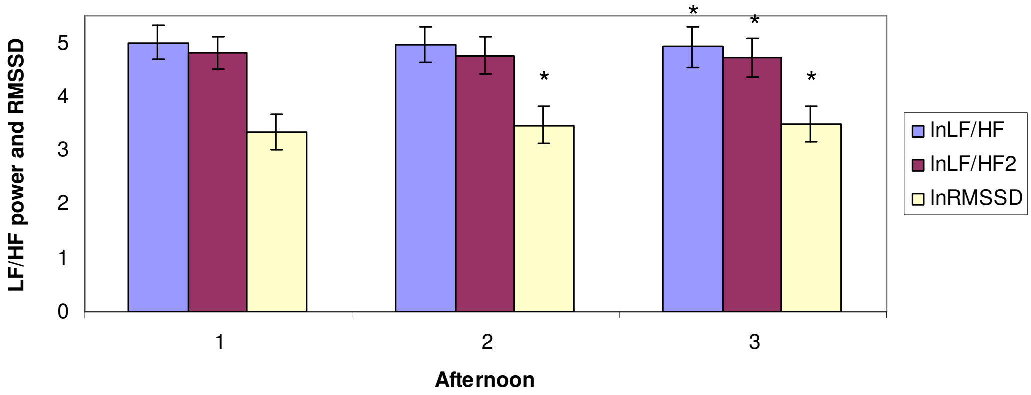

FIGURE 27. LF/HF powers and RMSSD during afternoons one, two and three. * = Significantly different from afternoon 1 ($p < .05$)

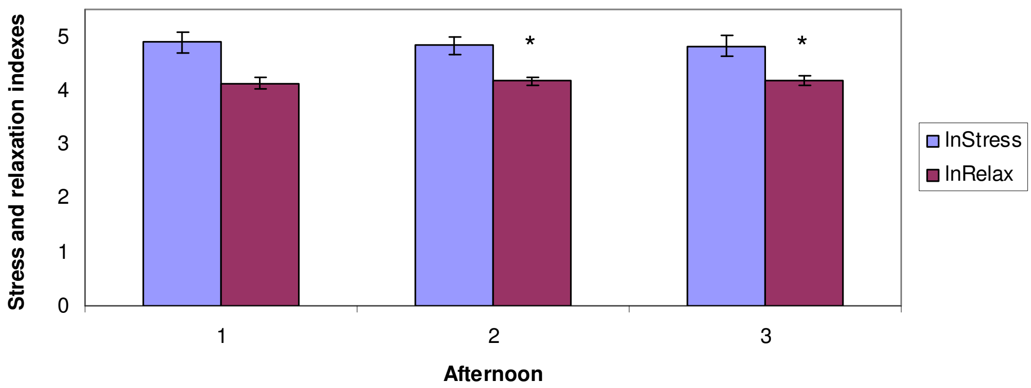

FIGURE 28. Stress and relaxation indexes during afternoons one, two and three. * = Significantly different from afternoon 1 ($p < .05$)

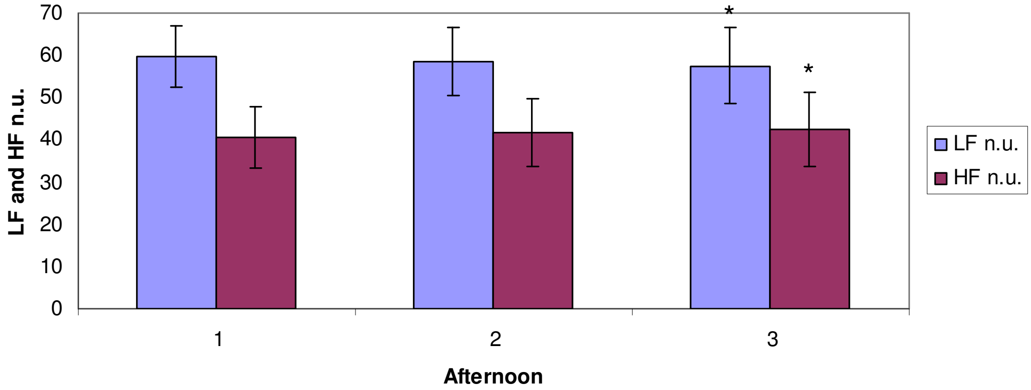

FIGURE 29. LF and HF normalized units during afternoons one, two and three. * = Significantly different from afternoon 1 ($p < .05$)

8.4 Associations between physical activity and HRV

There were several significant correlations between PA and HRV as well as between body composition and HRV. The main ones are presented here, and all the rest can be found in the appendix 2. Total amount of PA during the school day was positively correlated with lnStress and negatively with lnRMSSD for the average night. The amount of light PA during school hours also was in significant correlation with HRV variables for the average night (Table 7).

TABLE 7. Correlations between PA and HRV for the average night. >18H MVPA= Amount of moderate to vigorous PA later than 18:00 o'clock. Morning= Amount of light to vigorous PA during the morning, School= Amount of light to vigorous PA during the school day, Afternoon= Amount of light to vigorous PA during the afternoon. Morn.Light= Time of light PA during the morning, School Light= Time of light PA during the school day, Afternoon Light= Time of light PA during the afternoon.

Correlations for average nights													
		Active	Light	Moderate	Vigorous	MVPA	>18HMVPA	Morning	School	Afternoon	Morn. Light	School Light	Aftern. Light
HR	Pearson Correlation	0.27	0.33	-0.03	-0.06	-0.04	-0.06	0.13	0.36	-0.02	0.25	***0.42***	-0.02
	Sig. (2-tailed)	0.18	0.09	0.88	0.78	0.85	0.78	0.53	0.07	0.92	0.23	***0.03***	0.93
	N	27	27	27	27	27	26	25	27	27	25	27	27
LnVLF	Pearson Correlation	-0.19	-0.25	0.04	0.09	0.06	0.13	0.02	-0.27	-0.02	0.04	-0.37	-0.04
	Sig. (2-tailed)	0.35	0.21	0.83	0.67	0.78	0.52	0.92	0.18	0.93	0.86	0.06	0.86
	N	27	27	27	27	27	26	25	27	27	25	27	27
LnLF	Pearson Correlation	-0.14	-0.22	0.08	0.15	0.10	0.15	0.08	-0.29	0.04	0.10	***-0.40***	0.01
	Sig. (2-tailed)	0.48	0.26	0.68	0.46	0.61	0.46	0.69	0.14	0.85	0.65	***0.04***	0.98
	N	27	27	27	27	27	26	25	27	27	25	27	27
LnHF	Pearson Correlation	-0.14	-0.18	0.04	0.00	0.04	-0.05	0.09	-0.22	-0.04	0.07	-0.26	-0.06
	Sig. (2-tailed)	0.49	0.37	0.85	0.99	0.86	0.81	0.67	0.27	0.86	0.74	0.20	0.75
	N	27	27	27	27	27	26	25	27	27	25	27	27
LnHF2	Pearson Correlation	-0.14	-0.19	0.06	0.02	0.06	-0.06	0.11	-0.23	-0.04	0.07	-0.26	-0.08
	Sig. (2-tailed)	0.49	0.33	0.78	0.91	0.78	0.77	0.60	0.25	0.83	0.75	0.18	0.69
	N	27	27	27	27	27	26	25	27	27	25	27	27
LnStress	Pearson Correlation	0.22	0.32	-0.09	-0.16	-0.11	0.11	-0.17	***0.42***	0.09	-0.01	***0.47***	0.15
	Sig. (2-tailed)	0.27	0.10	0.66	0.42	0.59	0.58	0.43	***0.03***	0.65	0.96	***0.01***	0.45
	N	27	27	27	27	27	26	25	27	27	25	27	27
LnRelax	Pearson Correlation	-0.21	-0.27	0.04	0.04	0.04	-0.01	-0.02	-0.30	-0.02	-0.09	-0.35	-0.05
	Sig. (2-tailed)	0.29	0.17	0.85	0.85	0.83	0.97	0.95	0.14	0.90	0.68	0.08	0.83
	N	27	27	27	27	27	26	25	27	27	25	27	27
LnLFHF	Pearson Correlation	0.03	-0.02	0.06	0.21	0.09	0.30	-0.03	-0.06	0.13	0.02	-0.15	0.13
	Sig. (2-tailed)	0.89	0.94	0.78	0.30	0.67	0.13	0.90	0.75	0.51	0.94	0.46	0.51
	N	27	27	27	27	27	26	25	27	27	25	27	27
LnLFHF2	Pearson Correlation	0.03	0.01	0.02	0.17	0.05	0.32	-0.06	-0.05	0.15	0.02	-0.14	0.17
	Sig. (2-tailed)	0.87	0.96	0.91	0.39	0.80	0.11	0.77	0.82	0.45	0.93	0.50	0.41
	N	27	27	27	27	27	26	25	27	27	25	27	27
LnTot	Pearson Correlation	-0.15	-0.20	0.05	0.06	0.06	0.04	0.09	-0.26	-0.01	0.09	-0.32	-0.04
	Sig. (2-tailed)	0.46	0.31	0.80	0.76	0.78	0.84	0.66	0.20	0.96	0.67	0.10	0.85
	N	27	27	27	27	27	26	25	27	27	25	27	27
LnRMSSD	Pearson Correlation	-0.16	-0.18	0.00	0.01	0.00	-0.14	0.02	***-0.44***	0.09	-0.12	***-0.49***	0.09
	Sig. (2-tailed)	0.43	0.36	0.99	0.95	0.99	0.49	0.93	***0.02***	0.67	0.58	***0.01***	0.66
	N	27	27	27	27	27	26	25	27	27	25	27	27
LFnorm	Pearson Correlation	0.02	-0.02	0.05	0.22	0.08	0.32	-0.03	-0.05	0.11	0.03	-0.14	0.12
	Sig. (2-tailed)	0.91	0.93	0.82	0.27	0.69	0.11	0.89	0.80	0.57	0.87	0.48	0.55
	N	27	27	27	27	27	26	25	27	27	25	27	27
HFnorm	Pearson Correlation	-0.02	0.02	-0.05	-0.22	-0.08	-0.32	0.03	0.05	-0.11	-0.03	0.14	-0.12
	Sig. (2-tailed)	0.91	0.93	0.82	0.27	0.69	0.11	0.89	0.80	0.57	0.87	0.48	0.55
	N	27	27	27	27	27	26	25	27	27	25	27	27

When studying the three nights separately, it was found that for night three, there was a significant negative correlation between the total amount of light PA and lnRelaxation the following night. There were a positive correlation between light PA and HR as well as light PA and lnStress. Also the amounts of light PA during school and afternoon showed a relationship with $lnLF/HF^2$ and lnRMSSD respectively (Table 8). The correlation matrixes for night one and two are presented in appendix 2. The amount of school time PA, >18hMVPA and the amount of light PA during school hours, were correlated with night time HRV during the second night but no significant correlations between PA and HRV were found the first night.

TABLE 8. Correlations between day 3 PA and night 3 HRV.

Correlations day 3 night 3											
		Active	Light	MVPA	>18HMVPA	Morning	School	Afternoon	MorningLight	School Light	Aftern. Light
HR	Pearson Cor	.360	**.447**	-.040	-.064	.005	.187	.256	-.011	.379	.297
	Sig. (2-tailed	.084	**.029**	.854	.768	.983	.381	.228	.961	.068	.159
	N	24	24	24	24	24	24	24	24	24	24
LnVLF	Pearson Cor	-.132	-.262	.240	.279	.174	-.116	-.088	.244	-.352	-.146
	Sig. (2-tailed	.539	.216	.259	.188	.416	.591	.682	.250	.091	.495
	N	24	24	24	24	24	24	24	24	24	24
LnLF	Pearson Cor	-.026	-.178	.337	.316	.201	.009	-.059	.245	-.248	-.115
	Sig. (2-tailed	.903	.404	.107	.132	.347	.966	.785	.248	.243	.593
	N	24	24	24	24	24	24	24	24	24	24
LnHF	Pearson Cor	-.216	-.298	.091	.152	.139	.054	-.269	.177	-.085	-.368
	Sig. (2-tailed	.310	.158	.671	.478	.517	.804	.203	.407	.691	.076
	N	24	24	24	24	24	24	24	24	24	24
LnHF2	Pearson Cor	-.233	-.321	.099	.144	.161	.038	-.284	.185	-.100	-.390
	Sig. (2-tailed	.274	.126	.644	.501	.452	.861	.179	.386	.642	.060
	N	24	24	24	24	24	24	24	24	24	24
LnStress	Pearson Cor	.361	**.476**	-.104	-.107	-.298	.253	.292	-.237	.397	.388
	Sig. (2-tailed	.083	**.019**	.629	.618	.158	.233	.166	.264	.055	.061
	N	24	24	24	24	24	24	24	24	24	24
LnRelax	Pearson Cor	-.321	**-.411**	.065	.121	.094	-.059	-.303	.121	-.233	-.391
	Sig. (2-tailed	.126	**.046**	.761	.572	.662	.784	.151	.572	.274	.059
	N	24	24	24	24	24	24	24	24	24	24
LnLFHF	Pearson Cor	.276	.194	.310	.195	.063	-.065	.309	.067	-.202	.378
	Sig. (2-tailed	.193	.364	.141	.360	.770	.763	.142	.757	.345	.068
	N	24	24	24	24	24	24	24	24	24	24
LnLFHF2	Pearson Cor	.301	.228	.300	.207	.031	-.043	.332	.055	-.182	**.411**
	Sig. (2-tailed	.153	.283	.155	.331	.884	.843	.112	.798	.396	**.046**
	N	24	24	24	24	24	24	24	24	24	24
LnTot	Pearson Cor	-.137	-.254	.208	.250	.175	.039	-.184	.221	-.161	-.269
	Sig. (2-tailed	.523	.230	.328	.239	.413	.858	.388	.299	.453	.203
	N	24	24	24	24	24	24	24	24	24	24
LnRMSSD	Pearson Cor	-.096	-.102	-.028	.030	.207	-.398	.161	.152	**-.472**	.171
	Sig. (2-tailed	.657	.636	.896	.888	.331	.054	.451	.479	**.020**	.425
	N	24	24	24	24	24	24	24	24	24	24
LFnorm	Pearson Cor	.289	.211	.307	.205	.059	-.051	.314	.067	-.185	.388
	Sig. (2-tailed	.171	.323	.144	.336	.784	.813	.135	.757	.386	.061
	N	24	24	24	24	24	24	24	24	24	24
HFnorm	Pearson Cor	-.289	-.211	-.307	-.205	-.059	.051	-.314	-.067	.185	-.388
	Sig. (2-tailed	.171	.323	.144	.336	.784	.813	.135	.757	.386	.061
	N	24	24	24	24	24	24	24	24	24	24

There were significant correlations between daytime PA and daytime HRV for the three separate days (Appendix 2). It was seen that more PA at a particular time of day, had a positive effect on HR and markers of stress and a negative effect on vagal markers of HRV during these particular times of day. Figure 30 describes hour-by-hour the close relationship between PA and HR and HRV for one subject during day two.

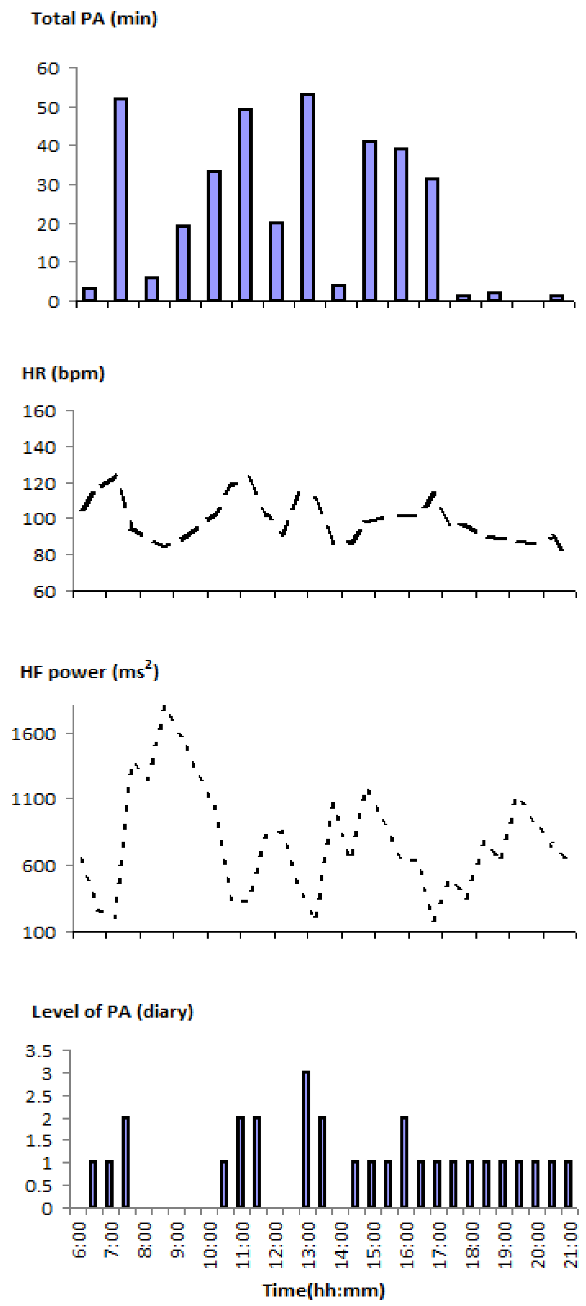

FIGURE 30. PA and HRV as diagrams for one girl the second day. The diagram on top shows the hour by hour amount of PA (total activity min/h) measured by Actigraph GT3X. The following two diagrams in the middle shows the corresponding HR and HF power curves. The lowest diagram is a conclusion of the self-reported events of physical activity hour by hour, based on the activity diary (See appendix 1).

Figure 31 presents the HR and HF power curves of two different subjects for the second night. Subject A had more MVPA and school time PA than subject B during the preceding day.

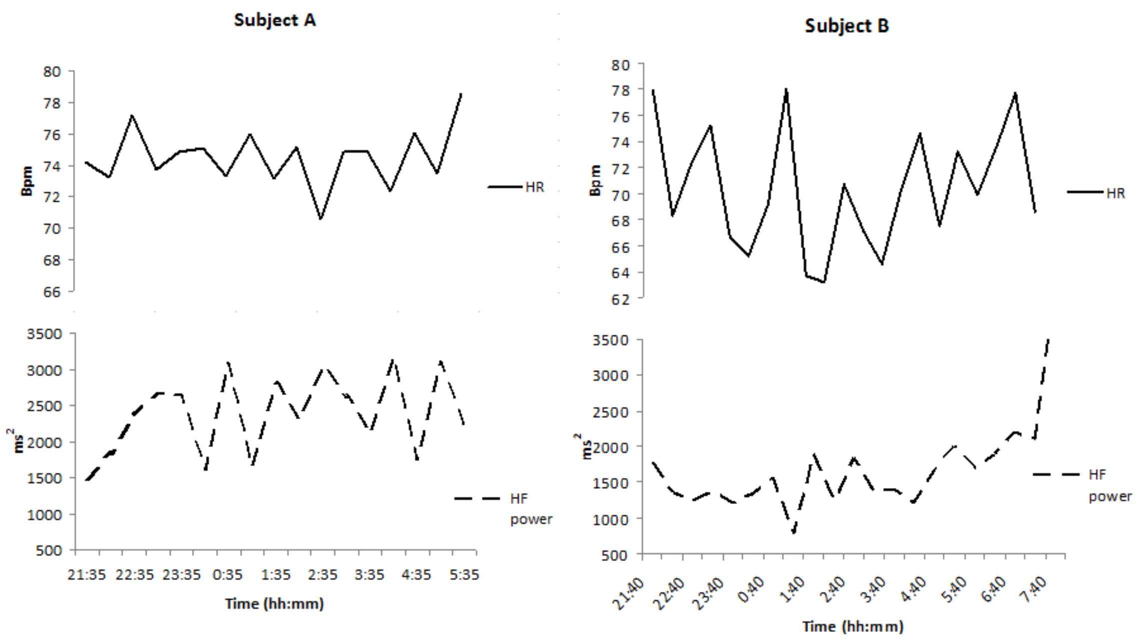

FIGURE 31. HR and HF power of two subjects for night two. Subject A had a total of 115 min MVPA and 127 min of school time activity while subject B had 12 min MVPA and 94 min school time activity during the preceding day.

8.5 Body composition and HRV

Fat % was inversely associated with average night time $\ln LF/HF^2$ (Table 9). Fat % correlated significantly with LF/HF and $\ln LF/HF^2$ also the first (r= -0.440) and the second night (r= -0.397) respectively. Furthermore, there were several significant but sporadic correlations between body composition and HRV for days (Appendix 2).

TABLE 9. Correlations between body composition and average night time HRV.

AVG nighttime HRV

		BM	Height	BMI	fat%	FFM
HR	Pearson Correlation	-.078	-.300	.048	.087	-.188
	Sig. (2-tailed)	.693	.120	.807	.660	.338
	N	28	28	28	28	28
LnVLF	Pearson Correlation	-.030	.248	-.178	-.212	.128
	Sig. (2-tailed)	.880	.204	.365	.280	.516
	N	28	28	28	28	28
LnLF	Pearson Correlation	-.061	.208	-.198	-.235	.087
	Sig. (2-tailed)	.756	.288	.313	.229	.658
	N	28	28	28	28	28
LnHF	Pearson Correlation	.007	-.015	.007	.034	-.040
	Sig. (2-tailed)	.971	.939	.973	.863	.840
	N	28	28	28	28	28
LnHF2	Pearson Correlation	.019	-.012	.019	.051	-.036
	Sig. (2-tailed)	.925	.952	.923	.795	.856
	N	28	28	28	28	28
LnStress	Pearson Correlation	-.021	-.036	.005	-.023	.003
	Sig. (2-tailed)	.916	.855	.980	.906	.986
	N	28	28	28	28	28
LnRelax	Pearson Correlation	.018	.110	-.037	-.030	.044
	Sig. (2-tailed)	.926	.579	.853	.881	.825
	N	28	28	28	28	28
LnLFHF	Pearson Correlation	-.076	.324	-.265	-.364	.201
	Sig. (2-tailed)	.700	.093	.173	.057	.304
	N	28	28	28	28	28
LnLFHF2	Pearson Correlation	-.095	.318	-.286	**-.391**	.193
	Sig. (2-tailed)	.630	.099	.140	**.040**	.325
	N	28	28	28	28	28
LnTot	Pearson Correlation	-.006	.088	-.064	-.060	.020
	Sig. (2-tailed)	.976	.655	.748	.762	.920
	N	28	28	28	28	28
LnRMSSD	Pearson Correlation	.147	.083	.137	.079	.076
	Sig. (2-tailed)	.454	.676	.487	.691	.703
	N	28	28	28	28	28
LFn.u.	Pearson Correlation	-.078	.321	-.263	-.360	.196
	Sig. (2-tailed)	.695	.096	.176	.060	.318
	N	28	28	28	28	28
HFn.u.	Pearson Correlation	.078	-.321	.263	.360	-.196
	Sig. (2-tailed)	.695	.096	.176	.060	.318
	N	28	28	28	28	28

9 DISCUSSION

The main result of this study was that PA did not show any clear association with night time HRV in children. There was a trend towards a positive association of the amount of light PA and school time PA on mean HR and Stress index during the following night. Anyhow, there was no consistent result showing that the amount or intensity of PA would have had an effect on the night time HRV.

Variation in HRV from day to day was seen as well as variation between different times of day. There were dose-response kind of associations between amount and intensity of daily physical activity and daytime HRV. Also some connections between body composition and HRV were found.

9.1 Associations between PA and HRV during daytime

A dose-response kind of relationship was found when studying the correlations for PA and daytime HRV day by day (Appendix 2). Morning, school time and afternoon PA cause rise in mean HR and most often stress index, and lowers the relaxation index and RMSSD and other vagal parameters of HRV. In figure 30, the relationship between PA and HR as well as the inverse relationship between PA and HF power for one subject are well established. It is natural, that with increasing PA, HR and the sympathetic drive to the heart increases. The acute effect of physical activity on HRV is something that has been observed in many studies (eg. Arai et al. 1989). It is known that also in children, onset of PA causes both parasympathetic and sympathetic actions to retrieve (Chen et al. 2008). The lack of studies measuring long time HRV and simultaneous PA in children results in less information about the actual effect that daily physical activity patterns have on HRV. Iwasa et al. (2005) followed one girl for 12 days and they reported a clear PA and HRV relationship, in the same way that this study. Their study clearly showed how the daytime PA of the girl corresponded to changes in mean HR, HF power and LF/HF ratio throughout the day. Also Bernardi et al. (1996) showed that habitual, random PA alters HRV. Long term HRV measurements are problematic as it becomes difficult to control environmental factors. Thus, it remains hard also in this study to conclude, where possible changes in HRV origin from. As it was done in the study of Iwasa et al. (2005), it would be necessary to follow the subjects over a longer period to be able to draw better conclusions about the association between habitual daily PA and HRV. In this present study, the measurement period was longer than in many others, but still too short for saying how strong the direct effect of random, habitual physical activity on HRV really is. Clearly there seems to be some connections.

9.2 Differences in HRV between times of day and day to day

The comparison between HRV from different times of day in this study, confirms a circadian variation of cardiac autonomic activity which has been known to exist also in children (Massin et al. 2010). Mean HR together with HF power, RMSSD and stress and relaxation indexes were all highest in the morning, suggesting that the morning time has the most HRV. Because the morning was a relatively short period of time, it may be that the effect of waking up and getting off to school can be seen more clearly. It is not encouraged to compare time domain variables from measurements of different lengths (Task Force 1999) and, therefore, should perhaps the comparison of RMSSD from different daytimes be interpreted with a caution. The morning (1-2 hours) before school is naturally a time with many different morning activities to be performed and commuting to school taking place. Thus the elevated sympathetic activity at this time is a logic response by the body. It is also known that morning awakening causes the sympathetic actions of the cardiac autonomic nervous system (CANS) to increase (Yeragani et al. 1996) and most variability at this time of day (Massin et al. 2000). Thus when morning time in this study was defined to begin from the time the child had reported that he or she got up, it may be that the higher HRV activities seen is caused to a great deal by the awakening itself and the increased sympathetic drive caused by the arousal of waking up. All vagal markers of HRV seem to reflect the fact that the afternoon has been the time for most parasympathetic activity of ANS. This is somewhat expected, as Massin et al. (2000) have shown that the circadian variation in HRV is much due to the withdrawal of the sympathetic activity. This may also be true in this study, and be an explanation for the more profound vagal actions seen in the afternoon.

When comparing HRV from the three different days with each other, it can be seen how the third day and the second morning (i.e. the third day) both seem to differ most from the two other days. The school day three is the most different in HRV compared with the other two days. The afternoons two and three seem to be more alike. It seems though that the third day was the day with most vagal CANS activity. It has been reported that HRV is a moderately reliable measurement in children (Leicht & Allen 2008) but wide inter-individual variation and day-to-day variations have also been reported (Pikkujämsä 1999; Iwasa et al. 2005). The variation between the days seen in this study is thus in line with earlier reported day-to-day variation of HRV. Because no direct connection between the level of PA and HRV for the three days was detected, it remains unclear whether this daily variation in HRV is due to differences in PA or caused by other factors. There was, however, no significant difference between PA of days two and three, and it remains therefore doubtful that PA would be the reason for the day-to-day variation of HRV.

9.3 Associations between PA and HRV for night time

When studying the average night, only school time PA and percentage body fat was significantly correlated with any HRV variable. In this case an inverse correlation was found between fat% and $lnLF/HF^2$ and school time PA and lnRMSSD respectively. A positive connection was observed between school time PA and lnStress, as well as the amount of light PA during school and mean HR and lnStress. The result between fat % and LF/HF ratio is in line with the knowledge that increases in body fat are related to reductions in cardiac autonomic activity, but in terms of LF/HF ratio, there has usually been seen a positive correlation. Studies in children comparing body composition and HRV seldom mention the relationship of fat% and HRV. In the study of Gutin et al. (2005), a higher fat% in children was related to a favorable parasympathetic modulation in white girls, whereas the higher fat% was negatively related to parasympathetic activity in black counterparts. It should be emphasized however, that the children in this study were not overweight but normal weight and therefore is the relevance of the seen result questionable.

According to current international criteria, a BMI ≤ 85th percentile is regarded normal weight for children. Referring to estimations of fat percentage, the criteria of normal weight would be < 25% in boys and < 30% in girls. (Strong et al. 2005.) In 11-12-year old Finnish boys, a BMI of 19.5-20.5 kg/m² would thus be the cut off for overweight and a BMI of 21-22 kg/m² in girls respectively (Käypä hoito-suositus 2005). There were only two boys and two girls in the group that met the criteria of overweight according to their BMI. The same two girls also had a fat% > 30 but only one of the boys also had a fat% over the recommended level. Based on this, the group can be regarded normal weight. It is not possible to compare waist circumference as it was not measured. The WC is often used as a measure of overweight and possible obesity in children (Krishnan et al. 2009, Gutin et al. 2005). Body composition all in all is a difficult matter in the pediatric group because of lack in standard recommendations and methods.

The association between school time PA and average night time HRV seen in this study is interesting, but as there were no significant correlations between the total amounts of PA or the different intensities of PA and HRV at average night, it remains difficult to conclude that habitual PA has an influence on night time HRV in children.

However, for separate nights there were some interesting correlations between PA and HRV (Table 8 and Appendix 3). As also seen in figure 31, there is a small difference in mean HR between the two subjects with different amounts of activity, so that the one with more MVPA and school time PA had a higher mean HR during the following night. These results are something of what was expected before the study. It was assumed that the amount and intensity of physical activity and, on the other hand, the amount of late night activity would reduce HRV and increases HR and sympathetic actions during the following night. This kind of results has been seen in adults, for example in the study of Myllymäki et al. (2010). They observed that late night vigorous PA increased HR during the night, but that it did not affect HRV. Hynynen et al. (2010) showed that both heavy and moderate intensity exercise during the day resulted in elevated HR and reduced HRV during the following night. In adolescents, Bricout et al. (2010) showed similar kind of results as Hynynen et al. (2010). The fact that in these examples of studies, the effects of PA on HRV at night has been measured during one night, allows one to speculate that maybe the relationships found, and also not found, between PA and HRV in the present study, are showing that physical activity can have an effect on nocturnal HRV also in young subjects. Because there is great individual variation in HRV from day-to-day, as well as variation in PA, the connection between these two can be difficult to detect over several days. The interesting part, though opposite to expectations, was that in this study, it was not the intense PA but the light PA that seemed to cause changes in HR and HRV variables during sleep.

There have been controversial findings in the literature regarding the effects of PA on HRV particularly in children. Some studies claim that it is rather the level of aerobic fitness than PA that modifies HRV in pediatric subjects (eg. Winsley 2002). There are also only a few studies which have measured the effect of PA on HRV at night or i.e. in actual resting state. Therefore, there is not much evidence to compare the results of this study with. One thing that seems crucial is the fact that in many pediatric studies, where PA and HRV have been studied, the possible effects of PA are seen in HR. The same trend could be noticed in this study, as often the relationship was found between PA and HR. The variables of stress and relaxation used in this study are based on mathematical models using HR as one factor in calculations. Therefore it seems logic that if a correlation between PA and HR is found, there are often also connections between PA and stress and relaxation. Maybe these modeled variables would be useful in future studies, particularly in children, to detect alternations in the ANS activity. In adult population, these calculated variables have been used successfully to describe physical and/or mental overloading and recovery and they seem to be quite easy to interpret also for not specialists in the field.

But why the relationship between PA and HRV was only seen sporadically in this study remains difficult to determine. When comparing PA levels between the three days, it seems that the second day has been the most active one, even though this was not statistically proven. For this day, there were, however, no connections between the total amount of light, MVPA or PA in general and HRV the following night. There was neither any difference in HRV between the three nights measured, even if there were some differences in PA between the days. HRV is obviously not a straight forward method, and it requires first of all good knowledge about the method itself but equally understanding about the physiology and neurophysiology of the heart. So many factors can influence the function of the myocardium, and PA is only one. In children, HR dynamics is a complex matter, as the nervous system is more flexible and still under development compared to adults (Massin & von Bernuth, 1997). Therefore maybe also the effect of habitual PA in children is only immediate, and does not have significant effects later on if the activity is not actually very intense or prolonged (compare studies of Bricout et al. 2010 or Iwasa et al. 2005).

9.4 Limitations

There are several limitations to the results in this study. First of all it should be noticed that the measurements took place in the mid-winter (February) when it was very cold. This can have reduced the amount of PA of the children, because of the hard weather conditions the children are not obliged to spend the breaks in school outside and it is less favorable to go outside to play in the free time when it is so cold.

Regarding the body composition, the use of bioimpedance is easy and also proven reliable in children, but the lack of the waist circumference is a weakness. The waist circumference is a widely used measure for body composition in children, and would therefore have provided better possibilities to compare the data with other studies. The children were asked to go on the toilet before the InBody measurement, thus the bias of fluid balance was tried to be controlled but eating was not controlled for.

HRV data was carefully edited, but there still remains a human error possibility, meaning that when dealing with a lot of data (72 hours, second-by-second), it is possible that some mistake in the editing have occurred. The splitting of the data also causes its own bias to the results, as it was based on the reports of the children. The diaries were not always that specific, and sometimes one had to look at the HRV data and estimate the beginning of sleep or the getting up time. When using the hours reported by the children, it also means that school day was defined between 8:00 o'clock and 13:00 o'clock sharp, if the child had reported so. In reality it is difficult to exactly determine the beginning and the end of a school day.

The number of subjects selected for this study was good, but maybe not big enough to show clear statistical relationships. For a scientific finding to be of value, it should need to be repeated. In this study the connections between PA and HRV were not seen systematically. As a descriptive study, it would have been good to have more subjects, because maybe then the statistical significance would have been seen more clearly. However, based on the findings of this study, it is easier to plan future intervention studies and perhaps target the focus on the amount of light PA or school time PA. A study design with control- vs. intervention group would allow better comparing the effects of PA on HRV and also drawing conclusions about the amount of PA needed to cause changes in HRV in healthy children. It would also have been valuable to have some data on the physical fitness of the children, as more information about the relationship between for example cardiorespiratory fitness and HRV exists also for children.

The fact that girls and boys were included in the same analyzes, also contributes to some error as there is known to be even large gender differences in this age category of children. It would not, however, have been appropriate to split the group by gender as the number of subjects was so low.

9.5 Conclusions

The main findings of this study were that habitual PA had no effect on average night HRV, but at separate nights there were some associations observed. Particularly light PA and school time PA caused higher HR and more sympathetic drive the following night. There were no differences in HRV between the three nights, but the variation between days and in daytime HRV was significant.

Based on the findings of the study, it still remains unclear if the level and intensity of habitual PA affects HRV in children. Daytime PA seems to influence HRV directly and this is a good argument for the positive effect of PA on cardiac health in children. What the long term effects of habitual PA on HRV are remains to be investigated. Future studies in children with longer HRV measurements and proper assessment of the PA level would be interesting to see. Many studies use only 10-15 min resting recordings to measure HRV and as seen also in this study, HRV can change already depending on the daytime. It is also well known that the night time is the time for many developmental processes and an important time for recovery and health. Thus night time would perhaps be appropriate to use for resting HRV measurements. Especially, if the goal is to reveal some health related connections of HRV. Studies comparing normal active and normal inactive subjects could also be helpful in revealing the effect of habitual PA on cardiac autonomic functions in children. Controlling for the amount of PA could diminish inter- and intra-individual variation, and thus be a useful way to clarify if PA causes changes in HRV. All in all, the role of cardiac autonomic function as a marker of health and health related fitness in children need to be considered and investigated further.

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Appendix 1. Physical activity diary.

FYYSISEN AKTIIVISUUDEN PÄIVÄKIRJA

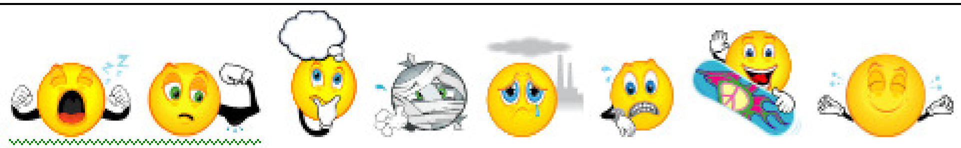
Nimi:______________________________ Päivä:_________________________

Tänään heräsin klo: ____:____ Eilen menin nukkumaan klo:____:____
Nukuitko hyvin? Kyllä Ei
Heräilitkö yöllä? Kyllä Ei Kuinka monta kertaa?________

Koulu alkoi klo:____:____ Koulu loppui klo:____:____ Montako välituntia koulussa oli? ______

Riisuitko mittauslaitteita tänään? Kyllä En
Milloin ja mitkä laitteet?

Fiilis tänään



Aamulla:	6:00-6:30	6:30-7:00	7:00-7:30	7:30-8:00	8:00-8:30	8:30-9:00	9:00-9:30	9:00-9:30
Makaaminen, makoilu, sohvalla loikoilu, lepääminen								
Istuminen, TV:n katselu, musiikin kuuntelu, lehtien lukeminen, läksyjen teko								
Kevyt liikkuminen, seisoskelu, vaatteiden pukeminen, siivous								
Kävely, kouluun kulkeminen, koiran ulkoiluttaminen, lumityöt								

Pyöräily, potkukelkkailu, pulkkailu								
Muu aktiivisuus, **mikä**?:								

Koulussa:	8:00-8:30	8:30-9:00	9:30-10:00	10:00-10:30	10:30-11.00	11:00-11:30	11:30-12:00	12:00-12:30	12:30-13:00	13:00-13:30	13:30-14:00	14:00-14:30	14:30-15:00
Makaaminen, makoilu, sohvalla loikoilu, lepääminen													
Tunnilla istuminen, musiikin kuuntelu, lukeminen, koulutöiden teko													
Kevyt liikkuminen, seisoskelu kavereiden kanssa, kävely välitunnilla													
Pelailu välitunnilla, lumileikit, potkukelkkailu, pulkkailu													
Liikuntatunti, mitä teitte?:													
Muu aktiivisuus, **mikä**?:													

Iltapäivällä:	12:00-12:30	12:30-13:00	13:00-13:30	13:30-14:00	14:00-14:30	14:30-15:00	15:00-15:30	15:30-16:00	16:00-16:30	16:30-17:00	17:00-17:30	17:30-18:00
Makaaminen, makoilu, sohvalla loikoilu, lepääminen												
Istuminen, TV:n katselu, tietokoneella olo, musiikin kuuntelu, lehtien lukeminen, läksyjen teko												

Kevyt liikkuminen, seisoskelu, vaatteiden pukeminen, siivous												
Kävely, koulusta kotiin kulkeminen, koiran ulkoiluttaminen, lumityöt												
Pyöräily, koulusta pyöräily, potkukelkkailu, pulkkailu												
Muu aktiivisuus, **mikä**?:												

Ilalla:	18:00-18:30	18:30-19:00	19:00-19:30	19:30-20:00	20:00-20:30	20:30-21:00	21:00-21:30	21:30-22:30	22:30-23:00	23:00-23:30	23:30-24:00
Makaaminen, makoilu, sohvalla loikoilu, lepääminen											
Istuminen, TV:n katselu, tietokoneella olo, musiikin kuuntelu, lehtien lukeminen, läksyjen teko											
Kevyt liikkuminen, seisoskelu, vaatteiden pukeminen, siivous											
Kävely, koiran ulkoiluttaminen, lumityöt											
Pyöräily, potkukelkkailu, pulkkailu											
Muu aktiivisuus, **mikä**?:											

Appendix 2. Correlations for different days.

Correlations day 1 night 1

		Active	Light	MVPA	>18HMVPA	School	Afternoon	School Light	Aftern. Light
HR	Pearson Correlation	.268	.288	.091	-.086	.208	.181	.105	.313
	Sig. (2-tailed)	.195	.163	.666	.683	.318	.387	.618	.128
	N	25	25	25	25	25	25	25	25
LnVLF	Pearson Correlation	-.118	-.151	-.003	.323	-.235	.045	-.125	-.102
	Sig. (2-tailed)	.575	.472	.987	.115	.257	.830	.553	.629
	N	25	25	25	25	25	25	25	25
LnLF	Pearson Correlation	-.046	-.122	.095	.325	-.258	.164	-.194	-.009
	Sig. (2-tailed)	.826	.560	.651	.112	.213	.433	.352	.967
	N	25	25	25	25	25	25	25	25
LnHF	Pearson Correlation	-.026	-.069	.054	.170	-.167	.133	-.079	-.009
	Sig. (2-tailed)	.902	.742	.797	.418	.424	.528	.707	.965
	N	25	25	25	25	25	25	25	25
LnHF2	Pearson Correlation	-.011	-.063	.075	.164	-.157	.146	-.082	.002
	Sig. (2-tailed)	.960	.766	.723	.433	.454	.485	.695	.991
	N	25	25	25	25	25	25	25	25
LnStress	Pearson Correlation	.011	.032	-.026	-.069	.182	-.163	.154	-.085
	Sig. (2-tailed)	.957	.880	.901	.744	.384	.438	.462	.685
	N	25	25	25	25	25	25	25	25
LnRelax	Pearson Correlation	-.131	-.163	-.009	.130	-.174	-.008	-.072	-.151
	Sig. (2-tailed)	.534	.435	.965	.537	.406	.971	.731	.471
	N	25	25	25	25	25	25	25	25
LnLFHF	Pearson Correlation	-.023	-.061	.047	.190	-.090	.009	-.154	.004
	Sig. (2-tailed)	.912	.771	.823	.363	.668	.967	.461	.986
	N	25	25	25	25	25	25	25	25
LnLFHF2	Pearson Correlation	-.052	-.075	.011	.204	-.113	-.013	-.150	-.018
	Sig. (2-tailed)	.805	.723	.959	.328	.590	.951	.475	.932
	N	25	25	25	25	25	25	25	25
LnTot	Pearson Correlation	-.041	-.099	.070	.244	-.214	.145	-.126	-.019
	Sig. (2-tailed)	.845	.636	.739	.240	.304	.488	.547	.929
	N	25	25	25	25	25	25	25	25
LnRMSSD	Pearson Correlation	.211	.133	.214	.150	.144	.211	.123	.127
	Sig. (2-tailed)	.312	.527	.304	.474	.492	.312	.557	.544
	N	25	25	25	25	25	25	25	25
LFnorm	Pearson Correlation	-.029	-.065	.042	.188	-.092	.003	-.152	-.003
	Sig. (2-tailed)	.891	.758	.844	.369	.661	.988	.469	.989

	N	25	25	25	25	25	25	25	25
HFnorm	Pearson Correlation	.029	.065	-.042	-.188	.092	-.003	.152	.003
	Sig. (2-tailed)	.891	.758	.844	.369	.661	.988	.469	.989
	N	25	25	25	25	25	25	25	25

Correlations day 2 night 2

		Active	Light	MVPA	>18HMVPA	Morning	School	Afternoon	MorningLight	School Light	Aftern. Light
HR	Pearson Correlation	.388	.296	.183	.252	.174	**.631**	-.093	.341	**.638**	-.106
	Sig. (2-tailed)	.055	.151	.382	.224	.406	**.001**	.659	.095	**.001**	.613
	N	25	25	25	25	25	25	25	25	25	25
LnVLF	Pearson Correlation	-.394	-.274	-.238	**-.403**	-.152	-.530	.004	-.246	**-.494**	.024
	Sig. (2-tailed)	.052	.186	.252	**.046**	.468	.006	.983	.235	**.012**	.909
	N	25	25	25	25	25	25	25	25	25	25
LnLF	Pearson Correlation	-.352	-.254	-.193	-.324	-.087	-.515	.019	-.168	**-.493**	.025
	Sig. (2-tailed)	.085	.220	.355	.114	.679	.008	.930	.422	**.012**	.905
	N	25	25	25	25	25	25	25	25	25	25
LnHF	Pearson Correlation	-.224	-.162	-.122	**-.436**	.035	-.353	-.009	-.090	-.319	.014
	Sig. (2-tailed)	.282	.439	.560	**.029**	.868	.083	.964	.668	.120	.947
	N	25	25	25	25	25	25	25	25	25	25
LnHF2	Pearson Correlation	-.230	-.175	-.109	**-.449**	.045	-.362	-.013	-.104	-.324	.006
	Sig. (2-tailed)	.269	.404	.603	**.024**	.832	.075	.950	.622	.114	.979
	N	25	25	25	25	25	25	25	25	25	25
LnStress	Pearson Correlation	.335	.328	.013	**.403**	.023	**.482**	.012	.277	**.490**	.035
	Sig. (2-tailed)	.101	.110	.951	**.046**	.913	**.015**	.953	.180	**.013**	.869
	N	25	25	25	25	25	25	25	25	25	25
LnRelax	Pearson Correlation	-.322	-.236	-.170	-.392	-.093	**-.508**	.042	-.260	**-.482**	.066
	Sig. (2-tailed)	.116	.256	.416	.052	.657	**.010**	.841	.209	**.015**	.754
	N	25	25	25	25	25	25	25	25	25	25
LnLFHF	Pearson Correlation	-.139	-.100	-.077	.284	-.196	-.158	.045	-.096	-.186	.013
	Sig. (2-tailed)	.507	.634	.714	.169	.347	.451	.830	.647	.374	.949
	N	25	25	25	25	25	25	25	25	25	25

LnLFHF2	Pearson Correlation	-.122	-.073	-.096	.302	-.208	-.134	.051	-.069	-.168	.027
	Sig. (2-tailed)	.562	.727	.647	.142	.319	.524	.810	.742	.423	.896
	N	25	25	25	25	25	25	25	25	25	25
LnTot	Pearson Correlation	-.285	-.203	-.163	**-.420**	-.011	**-.434**	.000	-.126	**-.399**	.020
	Sig. (2-tailed)	.167	.330	.436	**.037**	.959	**.030**	.999	.549	**.048**	.923
	N	25	25	25	25	25	25	25	25	25	25
LnRMSSD	Pearson Correlation	-.276	-.286	.021	**-.491**	.047	-.336	-.075	-.172	-.384	-.074
	Sig. (2-tailed)	.182	.166	.921	**.013**	.823	.100	.720	.411	.058	.726
	N	25	25	25	25	25	25	25	25	25	25
LFnorm	Pearson Correlation	-.131	-.090	-.081	.284	-.193	-.144	.042	-.092	-.166	.013
	Sig. (2-tailed)	.531	.668	.699	.170	.355	.493	.842	.661	.428	.953
	N	25	25	25	25	25	25	25	25	25	25
HFnorm	Pearson Correlation	.131	.090	.081	-.284	.193	.144	-.042	.092	.166	-.013
	Sig. (2-tailed)	.531	.668	.699	.170	.355	.493	.842	.661	.428	.953
	N	25	25	25	25	25	25	25	25	25	25

Correlations day 3 night 3

		Active	Light	MVPA	>18HMVPA	Morning	School	Afternoon	MorningLight	School Light	Aftern. Light
HR	Pearson Correlation	.360	**.447**	-.040	-.064	.005	.187	.256	-.011	.379	.297
	Sig. (2-tailed)	.084	**.029**	.854	.768	.983	.381	.228	.961	.068	.159
	N	24	24	24	24	24	24	24	24	24	24
LnVLF	Pearson Correlation	-.132	-.262	.240	.279	.174	-.116	-.088	.244	-.352	-.146
	Sig. (2-tailed)	.539	.216	.259	.188	.416	.591	.682	.250	.091	.495
	N	24	24	24	24	24	24	24	24	24	24
LnLF	Pearson Correlation	-.026	-.178	.337	.316	.201	.009	-.059	.245	-.248	-.115
	Sig. (2-tailed)	.903	.404	.107	.132	.347	.966	.785	.248	.243	.593
	N	24	24	24	24	24	24	24	24	24	24
LnHF	Pearson Correlation	-.216	-.298	.091	.152	.139	.054	-.269	.177	-.085	-.368
	Sig. (2-tailed)	.310	.158	.671	.478	.517	.804	.203	.407	.691	.076
	N	24	24	24	24	24	24	24	24	24	24
LnHF2	Pearson Correlation	-.233	-.321	.099	.144	.161	.038	-.284	.185	-.100	-.390

	Sig. (2-tailed)	.274	.126	.644	.501	.452	.861	.179	.386	.642	.060
	N	24	24	24	24	24	24	24	24	24	24
LnStress	Pearson Correlation	.361	**.476**	-.104	-.107	-.298	.253	.292	-.237	.397	.388
	Sig. (2-tailed)	.083	**.019**	.629	.618	.158	.233	.166	.264	.055	.061
	N	24	24	24	24	24	24	24	24	24	24
LnRelax	Pearson Correlation	-.321	**-.411**	.065	.121	.094	-.059	-.303	.121	-.233	-.391
	Sig. (2-tailed)	.126	**.046**	.761	.572	.662	.784	.151	.572	.274	.059
	N	24	24	24	24	24	24	24	24	24	24
LnLFHF	Pearson Correlation	.276	.194	.310	.195	.063	-.065	.309	.067	-.202	.378
	Sig. (2-tailed)	.193	.364	.141	.360	.770	.763	.142	.757	.345	.068
	N	24	24	24	24	24	24	24	24	24	24
LnLFHF2	Pearson Correlation	.301	.228	.300	.207	.031	-.043	.332	.055	-.182	**.411**
	Sig. (2-tailed)	.153	.283	.155	.331	.884	.843	.112	.798	.396	**.046**
	N	24	24	24	24	24	24	24	24	24	24
LnTot	Pearson Correlation	-.137	-.254	.208	.250	.175	.039	-.184	.221	-.161	-.269
	Sig. (2-tailed)	.523	.230	.328	.239	.413	.858	.388	.299	.453	.203
	N	24	24	24	24	24	24	24	24	24	24
LnRMSSD	Pearson Correlation	-.096	-.102	-.028	.030	.207	-.398	.161	.152	**-.472**	.171
	Sig. (2-tailed)	.657	.636	.896	.888	.331	.054	.451	.479	**.020**	.425
	N	24	24	24	24	24	24	24	24	24	24
LFnorm	Pearson Correlation	.289	.211	.307	.205	.059	-.051	.314	.067	-.185	.388
	Sig. (2-tailed)	.171	.323	.144	.336	.784	.813	.135	.757	.386	.061
	N	24	24	24	24	24	24	24	24	24	24
HFnorm	Pearson Correlation	-.289	-.211	-.307	-.205	-.059	.051	-.314	-.067	.185	-.388
	Sig. (2-tailed)	.171	.323	.144	.336	.784	.813	.135	.757	.386	.061
	N	24	24	24	24	24	24	24	24	24	24

Correlations day 1 – School time

School time		Active	Light	Moderate	Vigorous	MVPA	>18HMVPA	School	Afternoon	LightS	LightA	BM	Height	BMI	fat%	FFM
HR	Pearson Correlation	**,645**	**,542**	**,465**	.198	**,458**	-.031	**0.646**	**0.394**	**0.464**	**0.431**	-.188	-.326	-.100	.012	-.300
	Sig. (2-tailed)	**.000**	**.003**	**.015**	.323	**.016**	.876	**0.00**	**0.042**	**0.015**	**0.025**	.337	.091	.613	.952	.121
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnVLF	Pearson Correlation	-.257	-.208	-.198	-.077	-.194	.174	-0.254	-0.149	-0.069	-0.24	-.103	.130	-.192	-.126	-.021
	Sig. (2-tailed)	.195	.298	.322	.701	.332	.386	0.2	0.457	0.731	0.229	.602	.509	.326	.524	.916
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnLF	Pearson Correlation	-.244	-.254	-.099	-.072	-.101	.180	-0.26	-0.122	-0.099	-0.275	-.087	.185	-.199	-.133	.024
	Sig. (2-tailed)	.221	.202	.625	.722	.616	.368	0.19	0.546	0.623	0.165	.658	.347	.311	.501	.903
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnHF	Pearson Correlation	-.167	-.150	-.095	-.109	-.103	.124	-0.121	-0.114	0.026	-0.211	-.113	-.102	-.095	-.014	-.106
	Sig. (2-tailed)	.406	.455	.636	.588	.609	.538	0.547	0.572	0.898	0.292	.567	.604	.632	.944	.592
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnHF2	Pearson Correlation	-.194	-.176	-.113	-.096	-.118	.114	-0.156	-0.125	-0.012	-0.22	-.107	-.092	-.092	-.003	-.105
	Sig. (2-tailed)	.334	.380	.575	.633	.559	.572	0.437	0.534	0.953	0.269	.587	.641	.642	.986	.594
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnStress	Pearson Correlation	**,502****	.381	**,410***	.270	**,417***	-.057	**0.498**	0.298	0.267	0.34	.073	-.107	.131	.125	-.023
	Sig. (2-tailed)	**.008**	.050	**.034**	.173	**.031**	.776	**0.008**	0.131	0.178	0.082	.710	.589	.506	.527	.908
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnRelax	Pearson Correlation	**-,520****	**-,427***	**-,384***	-.192	**-,382***	.078	**-0.491**	-0.329	-0.286	**-0.388**	.050	.157	.000	-.027	.125
	Sig. (2-tailed)	**.005**	**.026**	**.048**	.336	**.049**	.700	**0.009**	0.094	0.149	**0.045**	.799	.424	.999	.891	.525
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnLF/HF	Pearson Correlation	-.076	-.121	.019	.085	.029	.055	-0.183	0.017	-0.198	-0.047	.065	**,455***	-.134	-.175	.220
	Sig. (2-tailed)	.705	.548	.925	.674	.886	.784	0.362	0.934	0.322	0.818	.743	**.015**	.498	.373	.261
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnLF/HF2	Pearson Correlation	-.047	-.096	.046	.059	.050	.090	-0.144	0.03	-0.144	-0.049	.051	**,471***	-.159	-.212	.232
	Sig. (2-tailed)	.817	.634	.821	.768	.803	.656	0.472	0.882	0.475	0.807	.795	**.011**	.418	.279	.236

	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnRMSSD	Pearson Correlation	**-.404***	-.354	-.265	-.144	-.265	.072	-0.376	-0.254	-0.206	-0.336	-.009	.073	-.041	.002	.030
	Sig. (2-tailed)	**.037**	.070	.182	.475	.182	.720	0.053	0.201	0.302	0.087	.965	.712	.837	.992	.881
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnTot	Pearson Correlation	-.239	-.232	-.120	-.103	-.125	.154	-0.231	-0.135	-0.064	-0.267	-.100	.077	-.163	-.091	-.027
	Sig. (2-tailed)	.229	.245	.552	.611	.535	.444	0.245	0.503	0.751	0.178	.611	.697	.406	.646	.893
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LFn.u,	Pearson Correlation	-.052	-.112	.052	.114	.063	.088	-0.158	0.035	-0.182	-0.041	.068	**.470***	-.139	-.179	.229
	Sig. (2-tailed)	.798	.579	.797	.571	.753	.662	0.43	0.864	0.362	0.838	.733	**.012**	.481	.363	.241
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
HFn.u.	Pearson Correlation	.052	.112	-.052	-.114	-.063	-.088	0.158	-0.035	0.182	0.041	-.068	**-.470***	.139	.179	-.229
	Sig. (2-tailed)	.798	.579	.797	.571	.753	.662	0.43	0.864	0.362	0.838	.733	**.012**	.481	.363	.241
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28

Correlations day 1 – Afternoon time

Afternoon		Active	Light	Moderate	Vigorous	MVPA	>18HMVPA	School	Afternoon	LightSchool	LightAfternoon	BM	Height	BMI	fat%	FFM
HR	Pearson Correlation	**.474***	.214	**.625****	.203	**.607****	**.484***	.057	**.629**	-.021	.336	-.030	-.182	.042	.107	-.141
	Sig. (2-tailed)	**.012**	.285	**.000**	.310	**.001**	**.011**	.776	**.000**	.918	.087	.880	.354	.831	.588	.474
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnVLF	Pearson Correlation	-.071	.123	-.317	-.186	-.319	-.209	.131	-.210	.209	-.007	-.108	.224	-.252	-.305	.086
	Sig. (2-tailed)	.723	.541	.107	.352	.105	.296	.516	.292	.295	.970	.586	.253	.195	.115	.664
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnLF	Pearson Correlation	-.229	-.067	-.364	-.062	-.346	-.012	-.046	-.276	.111	-.184	-.138	.197	-.283	-.260	.055
	Sig. (2-tailed)	.252	.742	.062	.758	.077	.952	.821	.164	.580	.357	.484	.315	.144	.182	.781
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnHF	Pearson Correlation	-.220	-.083	-.309	-.143	-.306	-.063	.042	-.319	.191	-.245	-.222	-.053	-.267	-.227	-.115
	Sig. (2-tailed)	.269	.681	.116	.476	.120	.755	.834	.105	.340	.218	.257	.790	.170	.246	.560
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28

LnHF2	Pearson Correlation	-.230	-.101	-.306	-.113	-.299	-.089	.043	-.331	.175	-.256	-.197	-.028	-.247	-.206	-.099
	Sig. (2-tailed)	.248	.617	.121	.575	.130	.658	.832	.091	.383	.198	.315	.888	.206	.293	.615
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnStress	Pearson Correlation	**,386** *	.140	**,542** **	.308	**,544** **	**,452** *	-.079	**.596**	-.231	.368	.175	-.088	.256	.257	.033
	Sig. (2-tailed)	**.046**	.485	**.003**	.119	**.003**	**.018**	.695	**.001**	.247	.059	.372	.656	.189	.187	.868
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnRelax	Pearson Correlation	**-,420** *	-.141	**-,620** **	-.243	**-,607** **	**-,452** *	.040	**-.617**	.168	-.333	-.136	.063	-.201	-.220	.003
	Sig. (2-tailed)	**.029**	.482	**.001**	.222	**.001**	**.018**	.845	**.001**	.401	.090	.489	.749	.305	.261	.989
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnLF/HF	Pearson Correlation	.079	.058	.050	.176	.069	.099	-.144	.194	-.194	.188	.211	**,403** *	.073	.032	.304
	Sig. (2-tailed)	.694	.775	.806	.381	.731	.623	.474	.331	.333	.348	.282	**.033**	.711	.870	.116
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnLF/HF2	Pearson Correlation	.071	.081	.006	.109	.020	.141	-.145	.182	-.147	.183	.145	.365	.006	-.032	.271
	Sig. (2-tailed)	.724	.688	.978	.587	.922	.482	.472	.363	.465	.362	.462	.056	.976	.873	.163
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnRMSSD	Pearson Correlation	-.363	-.194	**-,433** *	-.141	**-,421** *	-.268	-.001	**-.490**	.129	-.359	-.161	.045	-.231	-.205	-.062
	Sig. (2-tailed)	.063	.333	**.024**	.484	**.029**	.177	.994	**.009**	.521	.066	.412	.820	.238	.295	.753
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LnTot	Pearson Correlation	-.239	-.077	-.362	-.113	-.351	-.056	-.002	-.319	.158	-.226	-.189	.090	-.296	-.264	-.025
	Sig. (2-tailed)	.229	.702	.064	.574	.073	.782	.991	.105	.431	.258	.335	.648	.126	.175	.898
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
LFn.u,	Pearson Correlation	.091	.063	.064	.184	.084	.117	-.138	.208	-.191	.196	.223	**,414** *	.083	.037	.318
	Sig. (2-tailed)	.651	.755	.750	.358	.676	.560	.492	.298	.339	.327	.254	**.028**	.675	.851	.099
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28
HFn.u.	Pearson Correlation	-.091	-.063	-.064	-.184	-.084	-.117	.138	-.208	.191	-.196	-.223	**-,414** *	-.083	-.037	-.318
	Sig. (2-tailed)	.651	.755	.750	.358	.676	.560	.492	.298	.339	.327	.254	**.028**	.675	.851	.099
	N	27	27	27	27	27	27	27	27	27	27	28	28	28	28	28

Correlations day 2 – Morning time

Morning		Active	Light	Moderate	Vigorous	MVPA	>18HMVPA	Morning	School	Afternoon	LightM	LightS	LightA	Gender	BM	Height	BMI	fat%	FFM
HR	Pearson Correlation	.318	.179	.368	-.052	.361	.075	.370	.281	.026	.230	.311	-.052	-.201	-.271	-.159	-.254	-.185	-.256
	Sig. (2-tailed)	.139	.413	.084	.815	.091	.735	.083	.194	.905	.292	.149	.815	.324	.180	.439	.211	.367	.207
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnVLF	Pearson Correlation	-.170	-.043	-.277	-.120	-.305	.247	**-.488**	-.303	.210	-.390	-.294	.248	.201	.099	.155	.031	-.031	.132
	Sig. (2-tailed)	.438	.847	.201	.587	.157	.255	**.018**	.160	.335	.066	.174	.255	.325	.632	.451	.881	.881	.520
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnLF	Pearson Correlation	-.169	-.080	-.210	-.062	-.225	.109	**-.454**	-.287	.188	-.389	-.333	.228	.172	.059	.112	-.002	-.025	.070
	Sig. (2-tailed)	.440	.718	.336	.780	.301	.620	**.030**	.185	.390	.066	.121	.295	.401	.776	.586	.992	.904	.735
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnHF	Pearson Correlation	-.319	-.196	-.341	.080	-.327	-.093	**-.446**	-.218	-.051	-.324	-.278	.039	.002	-.032	-.155	.015	.066	-.123
	Sig. (2-tailed)	.138	.370	.111	.716	.127	.674	**.033**	.318	.818	.131	.199	.859	.992	.879	.451	.943	.747	.551
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnHF2	Pearson Correlation	-.311	-.188	-.341	.085	-.327	-.104	**-.438**	-.222	-.042	-.313	-.282	.048	-.004	-.018	-.145	.027	.088	-.119
	Sig. (2-tailed)	.148	.392	.111	.701	.128	.638	**.036**	.309	.850	.146	.192	.826	.985	.931	.480	.895	.670	.563
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnStress	Pearson Correlation	.176	-.041	**.473**[*]	.089	**.497**[*]	-.031	**.505**	.360	-.244	.303	.318	-.335	-.242	-.045	-.089	.002	.031	-.054
	Sig. (2-tailed)	.421	.854	**.023**	.687	**.016**	.887	**.014**	.092	.261	.160	.140	.118	.233	.825	.664	.991	.880	.794
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnRelax	Pearson Correlation	-.271	-.121	-.378	.042	-.373	.030	**-.461**	-.210	.006	-.283	-.253	.099	.065	.103	.028	.098	.094	.080
	Sig. (2-tailed)	.212	.582	.075	.848	.079	.893	**.027**	.335	.980	.191	.244	.653	.753	.617	.892	.634	.648	.698
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnLF/HF	Pearson Correlation	.356	.252	.341	-.230	.296	.318	.206	.012	.347	.069	.061	.237	.212	.127	**.403**[*]	-.028	-.144	.295
	Sig. (2-tailed)	.095	.247	.111	.291	.171	.139	.346	.955	.105	.754	.784	.277	.297	.536	**.041**	.893	.483	.143
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnLF/HF2	Pearson Correlation	.338	.235	.338	-.241	.290	.342	.179	.011	.337	.037	.060	.227	.229	.106	**.392**[*]	-.049	-.182	.293

	Sig. (2-tailed)	.114	.280	.115	.267	.180	.110	.413	.959	.116	.866	.787	.298	.261	.605	**.048**	.812	.374	.146
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnRMSSD	Pearson Correlation	-.282	-.155	-.342	.076	-.329	-.013	**-.439**	-.241	.009	-.274	-.316	.096	-.025	.068	-.055	.093	.150	-.029
	Sig. (2-tailed)	.192	.481	.110	.729	.125	.953	**.036**	.267	.968	.206	.142	.661	.904	.742	.791	.650	.466	.889
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnTot	Pearson Correlation	-.227	-.118	-.273	-.015	-.279	.042	**-.469**	-.267	.109	-.377	-.317	.171	.119	.019	.006	.000	.004	-.010
	Sig. (2-tailed)	.298	.593	.208	.946	.198	.849	**.024**	.218	.622	.076	.141	.436	.562	.925	.976	1.000	.985	.962
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LFn.u,	Pearson Correlation	.344	.234	.351	-.227	.307	.321	.202	-.006	.349	.056	.040	.232	.204	.152	**,429**[*]	-.012	-.129	.324
	Sig. (2-tailed)	.108	.284	.100	.298	.155	.135	.355	.979	.103	.801	.857	.286	.317	.459	**.029**	.954	.530	.106
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
HFn.u.	Pearson Correlation	-.344	-.234	-.351	.227	-.307	-.321	-.202	.006	-.349	-.056	-.040	-.232	-.204	-.152	**-,429**[*]	.012	.129	-.324
	Sig. (2-tailed)	.108	.284	.100	.298	.155	.135	.355	.979	.103	.801	.857	.286	.317	.459	**.029**	.954	.530	.106
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26

Correlations day 2 – School time

School		Active	Light	Moderate	Vigorous	MVPA	>18HMVPA	Morning	School	Afternoon	LightM	LightS	LightA	Gender	BM	Height	BMI	fat%	FFM
HR	Pearson Correlation	**,408**[*]	.255	.308	-.006	.303	.042	**.438**	**.767**	-.267	**.539**	**.685**	-.237	-.247	**-,433**[*]	**-,394**[*]	-.347	-.224	**-,448**[*]
	Sig. (2-tailed)	**.043**	.219	.135	.976	.140	.843	**.029**	**.000**	.197	**.005**	**.000**	.254	.206	**.021**	**.038**	.070	.253	**.017**
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnVLF	Pearson Correlation	-.229	-.098	-.252	-.062	-.261	.081	**-.497**	**-.553**	.329	**-.515**	**-.520**	.322	-.066	.066	.172	-.023	-.039	.125
	Sig. (2-tailed)	.270	.641	.224	.769	.207	.702	**.012**	**.004**	.108	**.008**	**.008**	.116	.740	.737	.382	.907	.842	.527
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnLF	Pearson Correlation	-.114	.043	-.271	-.247	-.314	.102	-.391	**-.502**	.377	-.364	**-.429**	.397	-.007	.092	.236	-.018	-.027	.174
	Sig. (2-tailed)	.586	.838	.190	.234	.127	.628	.053	**.011**	.063	.074	**.033**	.050	.972	.642	.226	.929	.893	.375

	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnHF	Pearson Correlation	-.258	-.053	-.381	-.170	**-,408***	-.069	**-.494**	**-.485**	.234	**-.432**	-.392	.280	-.128	.170	.030	.177	.214	.110
	Sig. (2-tailed)	.213	.801	.061	.416	**.043**	.743	**.012**	**.014**	.261	**.031**	.053	.175	.516	.386	.878	.367	.274	.578
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnHF2	Pearson Correlation	-.259	-.065	-.362	-.152	-.386	-.075	**-.488**	**-.509**	.249	**-.447**	**-.413**	.282	-.136	.208	.041	.219	.264	.122
	Sig. (2-tailed)	.211	.757	.076	.468	.057	.720	**.013**	**.009**	.231	**.025**	**.040**	.172	.489	.288	.835	.264	.174	.538
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnStress	Pearson Correlation	.220	.081	.253	.134	.275	-.019	**.413**	**.685**	**-.398**	**.508**	**.575**	-.372	-.031	-.333	-.258	-.281	-.237	-.293
	Sig. (2-tailed)	.292	.700	.222	.524	.183	.929	**.040**	**.000**	**.049**	**.009**	**.003**	.067	.877	.083	.185	.147	.224	.131
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnRelax	Pearson Correlation	-.351	-.167	-.358	-.065	-.367	.004	**-.534**	**-.720**	.324	**-.583**	**-.610**	.311	.094	.332	.254	.279	.210	.322
	Sig. (2-tailed)	.085	.426	.079	.757	.072	.983	**.006**	**.000**	.114	**.002**	**.001**	.130	.634	.085	.191	.150	.283	.094
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnLF/HF	Pearson Correlation	.332	.176	.323	-.060	.309	.304	.354	.158	.144	.275	.090	.082	.229	-.182	.294	-.357	**-,440***	.054
	Sig. (2-tailed)	.105	.400	.115	.777	.133	.140	.082	.452	.493	.183	.668	.696	.241	.354	.128	.062	**.019**	.787
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnLF/HF2	Pearson Correlation	.325	.201	.269	-.108	.246	.319	.320	.179	.132	.285	.109	.098	.240	-.244	.278	**-,428***	**-,525****	.038
	Sig. (2-tailed)	.113	.336	.194	.608	.235	.120	.119	.392	.529	.167	.604	.642	.219	.211	.152	**.023**	**.004**	.847
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnRMSSD	Pearson Correlation	-.264	-.069	-.365	-.146	-.388	-.044	**-.505**	**-.669**	.367	**-.494**	**-.551**	.369	-.051	.367	.167	.359	**,379***	.249
	Sig. (2-tailed)	.202	.744	.073	.487	.055	.833	**.010**	**.000**	.071	**.012**	**.004**	.069	.796	.055	.396	.060	**.047**	.201
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnTot	Pearson Correlation	-.172	.012	-.328	-.230	-.368	.040	**-.449**	**-.517**	.341	**-.403**	**-.433**	.373	-.056	.127	.163	.061	.069	.154
	Sig. (2-tailed)	.410	.955	.109	.268	.071	.850	**.024**	**.008**	.095	**.046**	**.031**	.066	.779	.518	.406	.759	.726	.433
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LFn.u,	Pearson Correlation	.331	.161	.348	-.043	.337	.321	.359	.154	.144	.258	.082	.074	.236	-.185	.314	-.373	**-,461***	.066
	Sig. (2-tailed)	.106	.441	.088	.838	.100	.118	.078	.462	.491	.212	.696	.726	.227	.345	.104	.051	**.014**	.738
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28

HFn.u.	Pearson Correlation	-.331	-.161	-.348	.043	-.337	-.321	-.359	-.154	-.144	-.258	-.082	-.074	-.236	.185	-.314	.373	**.461***	-.066
	Sig. (2-tailed)	.106	.441	.088	.838	.100	.118	.078	.462	.491	.212	.696	.726	.227	.345	.104	.051	**.014**	.738
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28

Correlations day 2 – Afternoon time

Afternoon		Active	Light	Moderate	Vigorous	MVPA	>18HMVPA	Morning	School	Afternoon	LightM	LightS	LightA	Gender	BM	Height	BMI	fat%	FFM
HR	Pearson Correlation	.322	.296	.037	.068	.049	**.406***	-.054	.306	.157	.210	.318	.114	**-.458***	-.284	**-.446***	-.151	.062	-,451*
	Sig. (2-tailed)	.117	.150	.860	.748	.815	**.044**	.799	.137	.454	.313	.121	.589	**.014**	.144	**.017**	.444	.755	.016
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnVLF	Pearson Correlation	-.286	-.088	-.362	-.199	-.395	-.229	-.214	**-.415**	.049	-.236	-.338	.154	.108	.101	.327	-.039	-.082	.238
	Sig. (2-tailed)	.165	.677	.075	.340	.050	.270	.304	**.039**	.816	.256	.099	.464	.584	.608	.089	.845	.677	.222
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnLF	Pearson Correlation	-.274	-.086	-.337	-.222	-.375	-.184	-.232	**-.474**	.115	-.256	-.391	.192	.148	.054	.323	-.098	-.135	.217
	Sig. (2-tailed)	.185	.683	.099	.285	.065	.379	.264	**.017**	.585	.218	.053	.359	.452	.784	.094	.620	.492	.267
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnHF	Pearson Correlation	-.251	-.043	**-.411***	-.042	**-.415***	-.234	-.301	-.305	.035	-.239	-.213	.136	.049	-.041	.004	-.062	-.076	.019
	Sig. (2-tailed)	.226	.839	**.041**	.842	**.039**	.259	.144	.139	.868	.251	.307	.516	.805	.836	.984	.754	.701	.923
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnHF2	Pearson Correlation	-.233	-.069	-.317	-.065	-.326	-.264	-.241	-.315	.043	-.271	-.220	.119	.059	.008	.031	-.012	-.021	.043
	Sig. (2-tailed)	.263	.744	.122	.759	.112	.202	.246	.125	.840	.189	.290	.571	.765	.966	.876	.953	.915	.827
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnStress	Pearson Correlation	.209	.112	.180	.076	.193	.255	.182	.180	.049	.310	.121	-.021	-.176	.032	-.105	.093	.172	-.097
	Sig. (2-tailed)	.316	.593	.389	.718	.357	.218	.384	.388	.815	.132	.566	.921	.370	.872	.594	.636	.382	.622
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnRelax	Pearson Correlation	-.268	-.132	-.261	-.057	-.269	-.297	-.192	-.288	-.031	-.290	-.230	.054	.271	.059	.202	-.023	-.143	.206
	Sig. (2-tailed)	.196	.529	.208	.785	.193	.149	.357	.163	.883	.160	.269	.798	.163	.764	.303	.906	.468	.292
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnLF/HF	Pearson Correlation	.086	-.041	.300	-.238	.253	.183	.240	-.098	.097	.089	-.155	.015	.117	.151	**.444***	-.023	-.050	.268

	Sig. (2-tailed)	.683	.845	.145	.252	.222	.381	.248	.641	.644	.674	.460	.944	.553	.442	**.018**	.908	.802	.167
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnLF/HF2	Pearson Correlation	.034	.003	.100	-.198	.062	.221	.109	-.098	.085	.132	-.154	.056	.103	.062	**,400***	-.117	-.153	.229
	Sig. (2-tailed)	.870	.987	.635	.342	.769	.288	.603	.640	.685	.529	.461	.792	.601	.756	**.035**	.552	.436	.241
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnRMSSD	Pearson Correlation	-.174	-.077	-.183	-.064	-.193	-.307	-.117	-.290	.046	-.244	-.212	.097	.115	.067	.095	.034	.016	.086
	Sig. (2-tailed)	.405	.715	.380	.760	.354	.135	.579	.160	.828	.239	.309	.645	.560	.736	.629	.862	.936	.665
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LnTot	Pearson Correlation	-.269	-.060	-.394	-.147	**-,418***	-.222	-.272	**-.407**	.082	-.246	-.315	.177	.105	.007	.180	-.088	-.112	.125
	Sig. (2-tailed)	.193	.777	.051	.483	**.038**	.286	.188	**.044**	.698	.235	.125	.397	.597	.972	.360	.658	.569	.526
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
LFn.u,	Pearson Correlation	.074	-.056	.307	-.238	.260	.192	.232	-.112	.098	.064	-.168	.011	.124	.162	,458*	-.017	-.051	.285
	Sig. (2-tailed)	.725	.789	.136	.252	.210	.358	.264	.593	.642	.761	.422	.958	.529	.410	.014	.931	.797	.141
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28
HFn.u.	Pearson Correlation	-.074	.056	-.307	.238	-.260	-.192	-.232	.112	-.098	-.064	.168	-.011	-.124	-.162	**-,458***	.017	.051	-.285
	Sig. (2-tailed)	.725	.789	.136	.252	.210	.358	.264	.593	.642	.761	.422	.958	.529	.410	**.014**	.931	.797	.141
	N	25	25	25	25	25	25	25	25	25	25	25	25	28	28	28	28	28	28

Correlations day 3 – Morning time

Morning		Active	Light	Moderate	Vigorous	MVPA	>18HMVPA	Morning	School	Afternoon	LightM	LightS	LightA	Gender	BM	Height	BMI	fat%	FFM
HR	Pearson Correlation	-.156	-.117	-.136	-.112	-.146	-.336	.298	.076	-.326	.336	.119	-.336	-.208	**-,397***	-.240	**-,385***	-.300	-.301
	Sig. (2-tailed)	.467	.585	.526	.602	.497	.108	.158	.724	.120	.109	.579	.109	.297	**.040**	.228	**.047**	.129	.127
	N	24	24	24	24	24	24	24	24	24	24	24	24	27	27	27	27	27	27
LnVLF	Pearson Correlation	.200	.294	-.116	-.106	-.126	.276	-.355	-.195	**.522**	-.259	-.046	**.482**	-.149	-.113	.052	-.211	-.154	-.052

	Sig. (2-tailed)	.350	.163	.588	.622	.556	.191	.089	.361	**.009**	.221	.831	**.017**	.459	.574	.795	.291	.442	.798
	N	24	24	24	24	24	24	24	24	24	24	24	24	27	27	27	27	27	27
LnLF	Pearson Correlation	.255	.240	.156	-.058	.135	.281	-.256	.021	.393	-.224	.074	.321	-.045	-.135	.137	-.261	-.226	-.066
	Sig. (2-tailed)	.229	.259	.466	.787	.529	.183	.228	.923	.057	.293	.731	.126	.825	.503	.497	.188	.257	.742
	N	24	24	24	24	24	24	24	24	24	24	24	24	27	27	27	27	27	27
LnHF	Pearson Correlation	-.135	-.140	-.024	-.122	-.044	.264	-.276	-.171	.115	-.306	-.181	.046	.046	.000	-.059	.016	.080	-.133
	Sig. (2-tailed)	.529	.515	.910	.570	.840	.212	.191	.425	.591	.146	.397	.833	.821	1.000	.769	.936	.693	.509
	N	24	24	24	24	24	24	24	24	24	24	24	24	27	27	27	27	27	27
LnHF2	Pearson Correlation	-.126	-.137	-.006	-.117	-.025	.283	-.242	-.179	.118	-.290	-.177	.042	.030	.048	-.040	.068	.144	-.112
	Sig. (2-tailed)	.558	.522	.980	.586	.907	.180	.254	.402	.581	.169	.408	.846	.883	.811	.842	.735	.473	.577
	N	24	24	24	24	24	24	24	24	24	24	24	24	27	27	27	27	27	27
LnStress	Pearson Correlation	-.063	-.108	.095	-.087	.074	**-,415***	**.439**	.033	-.275	.392	-.006	-.253	.097	-.051	.007	-.058	-.155	.062
	Sig. (2-tailed)	.770	.615	.658	.686	.732	**.044**	**.032**	.878	.194	.058	.976	.233	.630	.801	.971	.772	.440	.758
	N	24	24	24	24	24	24	24	24	24	24	24	24	27	27	27	27	27	27
LnRelax	Pearson Correlation	.052	.064	-.013	.035	-.006	.373	**-.433**	-.043	.265	**-.415**	-.052	.246	.100	.193	.071	.202	.198	.082
	Sig. (2-tailed)	.810	.765	.951	.872	.976	.073	**.034**	.842	.210	**.044**	.808	.246	.620	.335	.725	.313	.322	.686
	N	24	24	24	24	24	24	24	24	24	24	24	24	27	27	27	27	27	27
LnLF/HF	Pearson Correlation	**,430***	**,421***	.182	.115	.189	-.102	.143	.257	.211	.214	.322	.241	-.104	-.131	.212	-.276	-.326	.111
	Sig. (2-tailed)	**.036**	**.040**	.395	.593	.377	.634	.506	.225	.321	.315	.125	.257	.606	.514	.289	.163	.097	.581
	N	24	24	24	24	24	24	24	24	24	24	24	24	27	27	27	27	27	27
LnLF/HF2	Pearson Correlation	,405*	**,406***	.151	.106	.158	-.126	.094	.263	.200	.189	.308	.238	-.081	-.189	.181	-.335	**-,400***	.082
	Sig. (2-tailed)	.050	**.049**	.482	.623	.460	.556	.661	.215	.349	.377	.143	.262	.690	.344	.366	.088	**.039**	.683
	N	24	24	24	24	24	24	24	24	24	24	24	24	27	27	27	27	27	27
LnRMSSD	Pearson Correlation	-.039	-.059	.038	-.041	.028	.344	-.261	-.218	.233	-.305	-.218	.173	.059	.249	.095	.259	.319	.045
	Sig. (2-tailed)	.856	.784	.861	.849	.897	.100	.217	.307	.274	.147	.306	.418	.769	.210	.637	.193	.105	.822
	N	24	24	24	24	24	24	24	24	24	24	24	24	27	27	27	27	27	27
LnTot	Pearson Correlation	.085	.079	.067	-.088	.047	.293	-.311	-.066	.291	-.304	-.041	.224	-.009	-.093	.050	-.163	-.105	-.112
	Sig. (2-tailed)	.692	.713	.756	.684	.826	.165	.139	.760	.168	.149	.849	.293	.965	.643	.806	.416	.603	.577

	N	24	24	24	24	24	24	24	24	24	24	24	24	27	27	27	27	27	27
LFn.u,	Pearson Correlation	**.435**[*]	**.422**[*]	.195	.108	.200	-.092	.166	.247	.222	.237	.318	.238	-.108	-.125	.218	-.273	-.325	.116
	Sig. (2-tailed)	**.034**	**.040**	.360	.616	.348	.670	.437	.245	.298	.264	.130	.264	.591	.534	.275	.168	.098	.565
	N	24	24	24	24	24	24	24	24	24	24	24	24	27	27	27	27	27	27
HFn.u.	Pearson Correlation	**-,435**[*]	**-,422**[*]	-.195	-.108	-.200	.092	-.166	-.247	-.222	-.237	-.318	-.238	.108	.125	-.218	.273	.325	-.116
	Sig. (2-tailed)	**.034**	**.040**	.360	.616	.348	.670	.437	.245	.298	.264	.130	.264	.591	.534	.275	.168	.098	.565
	N	24	24	24	24	24	24	24	24	24	24	24	24	27	27	27	27	27	27

Correlations day 3 – School time

School		Active	Light	Moderate	Vigorous	MVPA	>18HMVPA	Morning	School	Afternoon	LightM	LightS	LightA	Gender	BM	Height	BMI	fat%	FFM
HR	Pearson Correlation	.116	.017	.249	.285	.279	-.032	.258	**.419**	-.249	.388	.217	-.244	.262	-.262	.017	-.325	**-,459**[*]	-.025
	Sig. (2-tailed)	.598	.940	.252	.188	.197	.884	.234	**.047**	.251	.067	.321	.261	.196	.197	.935	.105	**.018**	.902
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnVLF	Pearson Correlation	.188	.228	-.020	-.004	-.019	.391	-.171	-.064	**.426**	-.175	.082	.283	-.330	-.005	-.001	-.041	.112	-.119
	Sig. (2-tailed)	.390	.295	.927	.987	.931	.065	.434	.772	**.043**	.426	.710	.191	.100	.982	.995	.844	.588	.563
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26

LnLF	Pearson Correlation	.257	.261	.117	-.083	.091	.380	-.156	.068	.393	-.167	.162	.268	-.326	.033	.153	-.059	.087	-.004
	Sig. (2-tailed)	.237	.229	.596	.707	.679	.074	.476	.759	.064	.447	.460	.216	.104	.873	.455	.775	.672	.985
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnHF	Pearson Correlation	.003	.046	-.090	-.097	-.099	.342	-.197	-.078	.244	-.214	.046	.092	**-,401***	.077	-.102	.125	.263	-.091
	Sig. (2-tailed)	.990	.836	.684	.659	.652	.110	.367	.723	.261	.327	.835	.677	**,043**	.708	.621	.541	.194	.658
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnHF2	Pearson Correlation	.016	.049	-.057	-.108	-.072	.333	-.164	-.083	.245	-.213	.050	.093	**-,410***	.102	-.090	.152	.304	-.090
	Sig. (2-tailed)	.942	.823	.796	.625	.746	.121	.455	.706	.259	.329	.820	.671	**,037**	.619	.663	.460	.132	.662
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnStress	Pearson Correlation	.033	-.108	.305	.359	.344	-.015	.324	.230	-.277	.399	-.018	-.242	**,518****	-.040	.161	-.112	-.309	.188
	Sig. (2-tailed)	.880	.624	.156	.092	.108	.946	.132	.292	.201	.059	.934	.267	**,007**	.847	.432	.586	.124	.357
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnRelax	Pearson Correlation	-.070	.036	-.255	-.245	-.277	.176	-.295	-.264	.277	-.365	-.053	.192	**-,399***	.177	-.099	.252	**,406***	-.058
	Sig. (2-tailed)	.751	.869	.241	.261	.201	.422	.171	.223	.200	.087	.811	.379	**,043**	.387	.629	.215	**,039**	.777
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnLF/HF	Pearson Correlation	.329	.254	.320	.075	.306	-.149	.168	.235	.052	.185	.125	.177	.290	-.089	.338	-.271	-.332	.144
	Sig. (2-tailed)	.125	.242	.136	.735	.156	.497	.445	.281	.814	.397	.571	.420	.151	.665	.091	.181	.097	.481
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnLF/HF2	Pearson Correlation	.329	.271	.274	.092	.267	-.111	.098	.256	.076	.179	.130	.196	.294	-.131	.331	-.321	**-,400***	.145
	Sig. (2-tailed)	.125	.211	.205	.676	.218	.614	.655	.239	.732	.414	.553	.371	.145	.524	.099	.109	**,043**	.481
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnRMSSD	Pearson Correlation	.011	.075	-.121	-.204	-.147	.243	-.231	-.100	.237	-.321	.091	.131	**-,490***	.122	-.118	.194	**,392***	-.130
	Sig. (2-tailed)	.962	.733	.582	.351	.502	.263	.288	.651	.276	.135	.679	.553	**,011**	.551	.567	.341	**,048**	.527
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnTot	Pearson Correlation	.159	.185	.023	-.097	.003	.376	-.186	.011	.344	-.197	.124	.208	-.387	.054	.032	.028	.182	-.056
	Sig. (2-tailed)	.467	.398	.918	.659	.990	.077	.395	.962	.108	.367	.572	.340	.051	.793	.878	.891	.375	.787
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LFn.u,	Pearson	.336	.251	.347	.090	.332	-.136	.183	.233	.064	.196	.118	.173	.297	-.081	.362	-.274	-.339	.165

	Correlation																		
	Sig. (2-tailed)	.117	.249	.105	.683	.121	.535	.405	.285	.772	.370	.591	.429	.140	.696	.069	.175	.090	.420
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
HFn.u.	Pearson Correlation	-.336	-.251	-.347	-.090	-.332	.136	-.183	-.233	-.064	-.196	-.118	-.173	-.297	.081	-.362	.274	.339	-.165
	Sig. (2-tailed)	.117	.249	.105	.683	.121	.535	.405	.285	.772	.370	.591	.429	.140	.696	.069	.175	.090	.420
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26

Correlations day 3 – Afternoon time

Afternoon		Active	Light	Moderate	Vigorous	MVPA	>18HMVPA	Morning	School	Afternoon	LightM	LightS	LightA	Gender	BM	Height	BMI	fat%	FFM
HR	Pearson Correlation	**,611**[**]	**,585**[**]	.295	.185	.302	.276	.060	.097	**.602**	.144	.247	**.525**	-.280	.025	-.113	.065	.085	-.078
	Sig. (2-tailed)	**.002**	**.003**	.172	.399	.161	.202	.787	.658	**.002**	.512	.256	**.010**	.167	.902	.581	.752	.681	.703
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnVLF	Pearson Correlation	-.242	-.195	-.218	-.040	-.206	.247	-.191	-.002	-.120	-.077	-.029	-.199	-.182	-.203	.005	-.262	-.142	-.136
	Sig. (2-tailed)	.266	.373	.319	.855	.347	.256	.384	.993	.585	.728	.896	.363	.373	.320	.981	.196	.489	.509
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnLF	Pearson Correlation	-.167	-.150	-.085	-.159	-.107	.180	-.199	-.006	-.041	-.108	-.069	-.105	-.119	-.131	.136	-.234	-.162	-.018
	Sig. (2-tailed)	.446	.495	.699	.468	.628	.412	.362	.979	.853	.624	.753	.633	.564	.522	.509	.249	.430	.932
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnHF	Pearson Correlation	**-,435**[*]	-.357	-.360	-.145	-.354	.066	-.311	-.022	-.270	-.215	-.065	-.340	-.112	-.169	-.118	-.153	-.084	-.140
	Sig. (2-tailed)	**.038**	.094	.092	.510	.097	.766	.148	.919	.212	.324	.767	.113	.585	.408	.565	.455	.684	.494
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnHF2	Pearson Correlation	**-,476**[*]	**-,423**[*]	-.311	-.160	-.312	.046	-.216	-.043	-.332	-.186	-.071	**-.426**	-.108	-.122	-.106	-.097	-.010	-.131
	Sig. (2-tailed)	**.022**	**.044**	.149	.466	.147	.835	.321	.847	.122	.397	.746	**.043**	.599	.554	.608	.639	.962	.522
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnStress	Pearson Correlation	**,541**[**]	**,498**[*]	.310	.180	.315	.096	.118	-.031	**.532**	.136	.062	**.542**	-.016	.224	.116	.208	.134	.163

	Sig. (2-tailed)	.008	.016	.151	.412	.143	.663	.592	.887	.009	.535	.780	.008	.939	.271	.573	.308	.513	.428
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnRelax	Pearson Correlation	-,604**	-,530**	-.409	-.215	-.412	-.178	-.194	-.015	-.549	-.188	-.120	-.529	.095	-.170	-.045	-.177	-.145	-.076
	Sig. (2-tailed)	.002	.009	.053	.325	.051	.416	.375	.947	.007	.391	.586	.009	.645	.408	.826	.387	.479	.712
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnLF/HF	Pearson Correlation	,524*	,416*	,492*	.058	,459*	.093	.286	.030	.395	.231	.029	.438	.048	.126	.340	-.014	-.045	.206
	Sig. (2-tailed)	.010	.048	.017	.792	.028	.672	.186	.892	.062	.289	.896	.037	.814	.540	.089	.946	.828	.313
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnLF/HF2	Pearson Correlation	,572**	,507*	.401	.073	.378	.133	.118	.062	.486	.174	.035	.564	.034	.041	.321	-.116	-.170	.187
	Sig. (2-tailed)	.004	.014	.058	.740	.075	.544	.592	.780	.019	.428	.875	.005	.867	.841	.109	.574	.408	.360
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnRMSSD	Pearson Correlation	-,572**	-,540**	-.294	-.195	-.303	-.048	-.124	-.064	-.479	-.162	-.107	-.555	-.038	-.117	-.069	-.100	-.001	-.138
	Sig. (2-tailed)	.004	.008	.174	.373	.160	.828	.573	.772	.021	.461	.627	.006	.854	.568	.738	.626	.995	.501
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LnTot	Pearson Correlation	-.337	-.280	-.259	-.173	-.267	.121	-.289	-.018	-.183	-.187	-.074	-.244	-.124	-.166	.004	-.211	-.127	-.095
	Sig. (2-tailed)	.115	.195	.233	.431	.218	.584	.181	.934	.404	.392	.738	.262	.545	.417	.986	.302	.536	.645
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
LFn.u,	Pearson Correlation	,543**	,428*	,516*	.072	,483*	.111	.308	.039	.413	.254	.037	.441	.050	.135	.353	-.010	-.049	.222
	Sig. (2-tailed)	.007	.041	.012	.744	.020	.613	.152	.859	.050	.243	.866	.035	.807	.510	.077	.963	.813	.277
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26
HFn.u.	Pearson Correlation	-,543**	-,428*	-,516*	-.072	-,483*	-.111	-.308	-.039	-.413	-.254	-.037	-.441	-.050	-.135	-.353	.010	.049	-.222
	Sig. (2-tailed)	.007	.041	.012	.744	.020	.613	.152	.859	.050	.243	.866	.035	.807	.510	.077	.963	.813	.277
	N	23	23	23	23	23	23	23	23	23	23	23	23	26	26	26	26	26	26