Original Article

Effects of physical activity on Pupil cycle time (PCT) in healthy Indian male

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Abstract

Globally, physical inactivity is an important risk factor for the development of non-communicable disease consisting of coronary artery disease, as well as, other diseases including hypertension, diabetes, obesity, osteoporosis, and certain types of cancers. Parasympathetic nervous system (PNS) activity in the eye is determined by the pupil cycle time (PCT) can be comparable with cardiac parasympathetic response and thereby determine the morbidity and mortality among individuals. The PCT is measured by throwing white light on the edge of the pupil. Pupil cycling is a feature of pupillary reflex arc. The aim of this study is to establish the effect of physical activity on the PCT. The counting of PCT was done for 90 cycles and average one count is considered a single PCT. The physical activity level (PAL) was determined by administering a physical activity level questionnaire developed in the Division of Nutrition, St. John’s Medical College, Bangalore. The PAL is classified as <1.4 as sedentary, 1.55 to 1.75 moderately active, and >1.75 heavily active. Thirty healthy male volunteers in the age group of 18-50 years and with BMI of 18.5 kg/m²–30 kg/m² were studied. We obtained PCT of 962.00±105.72 msec in sedentary, 896.77±85.88 msec in moderately active and 889.45±68.71 msec in heavily active individuals. Linear regression analysis shows there is statistically significant difference between the three different groups of physical activity level with a b value of 0 and R² being 0.19. Increase in physical activity led to decrease in the PCT i.e. increase in the parasympathetic tone in the eye. Pupil cycle time (PCT) is a simple noninvasive tool to assess and differentiate the PNS function in different activity level of individual.

Introduction

Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy...
expenditure and encompasses both leisure time activity (sports, exercise) and activities of daily life. Physical activity in daily life can be categorized into occupational, sports, conditioning, household or other activities (1). Physical inactivity is an important risk factor for the development of cardiovascular diseases (2, 3), the other diseases like non-insulin dependent diabetes mellitus, obesity, Chronic respiratory diseases, osteoporosis, and certain types of cancers (3, 4) which make up to 60% of all deaths. The problem is of particular concern in those countries that have transitional economics like India. Some data suggest that Indians has genetically determined risk factor for coronary artery diseases (5, 6) and physical inactivity would tend to increase the risk. It is estimated that 2.4% of US health care expenditure is directly related to lack of physical activity (6, 7). Disorder in the parasympathetic nervous system (PNS) activity causes the increased risk of heart disease, diabetes etc (7). So, we found it necessary to assess the physical activity and how it is related to the parasympathetic activity in the eye.

Many lifestyle factors may affect autonomic function. The long term physical activity on autonomic cardiovascular regulation has been addressed in several studies (8, 9). The possible beneficial effects of physical activity on autonomic cardiac regulations are assumed to be resulting from the vagotonic effect and parasympathetic dominance by long term physical training. It is suggested the training bradycardia in previously sedentary individuals after a short-term training period is due both to a reduced beta-adrenergic receptor activity and an increased parasympathetic activity (8, 9, 10).

The pupil cycle time (PCT) is defined as the time required for a single cycle of constriction and dilatation of the pupil when a single beam of light is projected on the edge of the pupil after complete dark adaptation (11-16). This is a method of studying only the parasympathetic nervous system function in the eye (11, 12, 17) which can be separated from the sympathetic activity (9). Pupil cycle time is studied extensively with age (17), the two eyes (14), gender, hormones (15), different types of instruments and techniques (14), states of nutrition (12) but they did not study it in different physical activity levels of population. The pupillary oscillation is studied before using oscillometer and various drugs affecting ANS in the eye to establish parasympathetic dysfunction in obesity (8, 9). In 1990, Lanting et al showed that the pupillary parasympathetic dysfunction occurred earlier than cardiovascular system when he considered darkness pupil latency as ophthalmologic tests and response to standing and response to deep breathing as parasympathetic cardiovascular tests (18). Martyn et al correlated well with the cardiac autonomic function tests and opined that compared to CVS tests PCT is 59% sensitive and 70% specific. They also opined that Integrity of pupillary reflex pathway is required for this light reflex. Pharmacological studies have demonstrated that PCT is mainly determined by integrity of the parasympathetic nerve supply in the iris (19).

The present cross-sectional study investigates how the different level of physical activity affect the pupil cycle time (PCT), and thereby investigates the parasympathetic response in the eye. As the PCT is comparable with the parasympathetic response in the heart, we can assess the morbidity and mortality of the subjects (16). The objective of this study is to find the effect of measurable physical activity on the parasympathetic response in the eye. Parasympathetic response in the eye is determined by pupil cycle time (PCT) which is supported by many literatures mentioned above.

Material and Methods

Recruitment of subjects

We have recruited fifteen (15) subjects for pilot study. Sixty-four subjects (64) were initially recruited from the student, staff and general population in and around St. John’s Medical College. Thirty-four (34) of them who had history of asthma, diabetes, hypertension, hypotension, any ophthalmologic problem like optic neuritis, compressive optic neuropathy, glaucoma, atrophic papilloedema, traumatic optic neuropathy, ischaemic optic neuropathy or on medication were excluded from the study. Alcoholics taking more than two standard drinks per day were also excluded and the smokers were instructed to abstain from smoking for 24 hours. Thirty healthy
male adults in the age range of 18-50 years were introduced to the questionnaire after taking informed consent and divided into three groups according to their PAL. Subjects having BMI ranging from 16 kg/m\(^2\)–30 kg/m\(^2\) were included in the study (12).

Ethical approval was obtained prior to the study from the Ethical Committee, St John’s Medical College, Bangalore.

**Anthropometric measurement**

Body mass index (BMI): Body weight of the subjects was measured to the nearest 0.001 kg using a sensitive electronic scale (Fitness, Edryl, India) and height was measured using a stadiometer (Nivostise Brivete depose). Body mass index (BMI) was calculated using Quetlet’s index (weight in kilogram/height in meter squared).

Mid arm circumference (MAC)

The MAC was measured in the right arm. Firstly, measurement was taken from the tip of the coracoids process to the tip of the olecrenon process as the anatomical landmark and the midpoint was decided on the lateral side. The MAC was measured on the midpoint around the arm by a simple measuring tape. Mid arm circumference was measured to avoid the bias considering only the BMI as the nutritional status.

**Measurement of pupil cycle time (PCT)**

The subject was seated for 15 minutes at the slit-lamp after entering the dimly light examination room to allow time for dark adaptation (12, 15, 16). The slit lamp was adjusted to a comfortable height for both the subject and examiner. Then the subject was instructed to gaze to an imaginary infinity. The slit lamp was put on and the beam of light was focused on the edge of the pupil of one eye from below. The constriction and dilatation of pupil started and that was counted for 30 cycles.

The subject was then rested for 15 minutes and the counts were repeated. Three sets of 30 cycles were noted. The same procedure was followed for the other eye. If any problem like watering, too many blinking or illumination occurred during the measurement of any sets of 30 cycles, the entire reading was discarded.

The stopwatch has an oscillator of 1 kHz, which gives an accuracy of 1 millisecond. The counter started the stopwatch at the beginning and at the end of the preselected number of cycles; which reduced human error to a minimum. The PCT is measured in both the eyes (12). The PCT which was of longer duration in the two eyes was taken into consideration for analysis (12, 16, 17, 18).

**Measurement of physical activity level (PAL)**

Physical activity is assessed by several methods including diaries, time and motion studies, motion sensors and stable isotope methods. These methods are, however, costly and cannot easily be applied to large populations. In contrast, questionnaire was easy to administer, cost effective and applicable to the study of larger populations.

Physical activity level was used as an index of physical activity patterns and was calculated as:

\[
\text{PAL} = \frac{24 \text{ hour energy expenditure}}{\text{Basal metabolic rate (BMR)}}
\]

Twenty-four hour energy expenditure is calculated as the sum of energy expenditures of all reported activities computed for a single day. Basal metabolic
rate (BMR) was calculated from age and gender specific regression equations recommended by the WHO (23) that include height and weight as predictor variables.

The cut-offs for PALs that describe grades of physical activity are:

- $<1.4 = \text{Sedentary}$
- $1.55-1.6 = \text{moderately active}$
- $>1.75 = \text{heavily active}$

Thus lower PALs indicate more sedentary physical profiles.

**Twenty-four hour energy expenditure**

The activities reported of 4 weeks recomputed for 24 hours as the sum of energy expenditure related to sleep, occupational energy expenditure, discretionary leisure-time energy expenditure and ‘residual energy expenditure’. In order to calculate energy expenditure for each of these components BMR/min is computed first. For every reported activity a MET (metabolic equivalent) which is essentially a multiple of BMR is applied. In 1993, for occupational activity, use of METs for various job descriptions in different purposes was applied (24). The higher MET indicated higher levels of physical activity. Residual energy expenditure relates to those periods in a day which are unaccounted for by recall, and for which intensities of activities have to be assumed. This is a common problem in physical activity level questionnaires. In literature, validated physical activity questionnaires have had up to 6 hours of residual time. Since report from various literatures suggests that individuals tend to underreport sedentary activities, a uniform MET of 1.4 was applied for all residual time (3, 17, 18). This required 30 minutes to complete.

A retrospective physical activity level (PAL) questionnaire is provided with this article.

**Results**

Data were expressed in mean±SD. Table I shows the subject characteristics of study population. After introducing the physical activity questionnaire to the subjects, 24-hours activities were noted down which they were used to do normally for last 4 weeks. We fed the MET value in the computer software and we obtained the PAL value of each subject. The linear regression analysis was run with the data of PAL and PCT. The effect of physical activity of the subjects showed that with increased PAL there was a decrease of PCT with a negative relation with $R^2$ value of 0.193 which was statistically significant (b=0). Decrease of PCT means the increased parasympathetic tone in the eye which is inversely proportional (12). We also observed the statistically insignificant age variation with the physical activity level. In this study we obtained a parallel line with minimal difference with $R^2$ value of 0.048 when a linear regression analysis was applied in three groups which were statistically not very significant. The study is age-matched and BMI-matched.

**Discussion**

The present study aimed to assess the effect of habitual physical activity on parasympathetic response in the eye i.e. pupil cycle time (PCT) with physical activity level (PAL) as the main indicator. Only male subjects were considered as female sex hormones have shown to affect the autonomic nervous system activity with respect to heart rate variability and cardiac autonomic function (16). A BMI range of 18.5 kg/m²-30 kg/m² was considered as pupillary autonomic activity changes in various state of nutrition. The MAC was calculated to exclude the undernourished or obese people. The average MAC range was 24-30 cm in the three groups which was within normal limits (12). The Sympatho-vagal balance fluctuates with ageing. Autonomic nervous activity in relation to ageing was studied using conventional

<table>
<thead>
<tr>
<th>Subject characteristics</th>
<th>Sedentary (n=6)</th>
<th>Moderately active (n=13)</th>
<th>Heavily active (n=11)</th>
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</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>37.17±9.81</td>
<td>30.69±7.18</td>
<td>33.36±10.74</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.28±3.66</td>
<td>23.16±3.82</td>
<td>21.70±2.00</td>
</tr>
<tr>
<td>MAC (cm)</td>
<td>28.00±2.68</td>
<td>28.25±4.18</td>
<td>25.75±1.88</td>
</tr>
<tr>
<td>PAL</td>
<td>1.31±0.10</td>
<td>1.62±0.12</td>
<td>1.86±0.08</td>
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<td>PCT (msec)</td>
<td>962.50±105.72</td>
<td>896.77±85.88</td>
<td>889.45±68.71</td>
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cardiac autonomic function tests (17, 26). Age-related reductions in overall heart rate variation in response to deep breathing and Valsalva maneuver suggest that ageing is associated with impaired vagal control of heart rate. Most of the currently available data on the effect of age on autonomic nervous function is derived from studies of heart rare variability (HRV), reporting that increasing age is associated with a reduction in overall HRV. Studies on confounding variables of cardiovascular autonomic function had revealed that age is one of the important confounders for cardiac autonomic function (8, 17, 25, 26). As age is considered as the confounding factor in the measurement of autonomic activity, we chose the subjects between the age group of 18-50 yrs where statistically insignificant variation may occur (12).

The development of coronary artery disease, as well as, other diseases including hypertension, diabetes, obesity, osteoporosis, certain type of cancer occurs from the physical inactivity (1). The tone of the parasympathetic nervous system is directly proportional to PAL. The increase of PCT means decrease of the PNS tone in the eye. The PNS tone corroborates with the findings of the cardiovascular system (12, 17, 25). The morbidity and mortality increases with decrease of PNS tone which is documented in literatures (13, 17, 25, 26, 27, 28). In this present cross-sectional study, it was found that an increase of PAL of subjects causes a decrease in PCT i.e. they were inversely proportional to each other. The PAL value was obtained after introducing physical activity level questionnaire to the subjects. The questionnaire constitutes a simple, feasible method of assessing physical profile. Its repeatability and relative validity are similar for physical activity questionnaire used in western populations (4, 21, 29, 30). Application of the questionnaire to Indian population provides valuable insights into the physical activity patterns. The authors of the PAL questionnaire emphasize that it is designed for the evaluation of quantifiable PAL in epidemiological use, although some insight can certainly gained into the individual subject. They also did by delineating as many activities as possible over a prompted recall of 4weeks. The time period was short enough to reduce recall bias (22). In this study, we found that the PCT was inversely correlated with PAL; that means there is an increase of duration of PCT with decrease of PAL and vice versa.

In 1986, functional correlates of PCT were studied by Martyn and Ewing (19). Miller and Thompson were among the first to investigate the method of PCT in 1978(13). They incorporated a method that we have followed closely in our study. We have used more accurate timer which can measure the duration with 0.001-second accuracy against 0.01-second used by them. Our study required 2 minutes as against 5 minutes taken by the earlier studies. Thus the ambient light was maintained in the same subject and study was conducted in same time (18-22). In 1993, again interest in PCT has also been raised by the exploration of the hypothesis that open angle glaucoma (OAG) has an autonomic neuropathy component which also investigated the cardiovascular autonomic function and found that there was presence of prolonged PCT in patients with OAG compared to normal people without OAG and that is comparable with the cardiovascular autonomic function test (16). Using this approach, PCT measurements have since been made in wide variety of optic neuropathies (optic neuritis, compressive optic neuropathy, glaucoma, atrophic papilloedema, traumatic optic neuropathy, and ischaemic optic neuropathy) (15, 16, 19, 20, 21). So, we took care to choose the subject devoid of any of these diseases.

It is suggested that the training bradycardia in previously sedentary individuals after a short-term training period in due both to a reduced beta-adrenergic receptor activity and an increased parasympathetic activity. Rastogi T, Vaz et. al concluded in their study that adverse health consequence of physical inactivity and the importance of leisure–time exercise in the prevention of CHD risk among Indians. Given limited resources for the care of CHD and the potential benefit of exercise in urban India where physical activity are now comparable with the west. Population–based health should focus on promoting regular physical exercise (3, 30). Our results also support this phenomenon.

In this cross-sectional study, we observed that there
PHYSICAL ACTIVITY QUESTIONNAIRE (URBAN)

Name: Study Code: ________________________________

Stated Occupation: ____________________________
Age: ____________________________ M/F
Height (cms): ____________________________ Weight (kgs): ____________________________

1. a) On an average, how many hours per day do you spend at work: _______
1. b) How many days in a week do you work: _______
1. c) Of the hours you spend at work, how many hours do you spend:

<table>
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<tr>
<th>Standing</th>
<th>Sitting</th>
<th>Walking</th>
<th>On activities more strenuous than walking</th>
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2) On an average, how many hours do you sleep in a day: _______

3) Apart from work, how do you spend your time. Fill in the table below.

<table>
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<tr>
<th>Type of Activity</th>
<th>(Over the last month)</th>
<th>Average Duration (mins)</th>
<th>Daily</th>
<th>Weekly</th>
<th>Monthly</th>
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<td>Sports/games/exercise</td>
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<td>Hobbies involving manual labour (for eg. Carpentry, gardening ........... etc.)</td>
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<td>Household chores (for eg. sweeping, cooking, washing ........... etc.)</td>
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<td>Sedentary activities for e.g. Reading, watching TV ........... etc.)</td>
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<td>Other Activities</td>
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<td>1. Eating</td>
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<td>2. Brushing &amp; Bathing</td>
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<td>3. Dressing</td>
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<td>4. Socializing (talking)</td>
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<td>5. Traveling to and from work</td>
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4) How do you normally travel to and from work: _______


is a slower reaction time with lengthening of PCT with decrease of physical activity. We obtained an average PCT of 962.00±105.72msec in the sedentarily active people with average PAL value of 1.31±0.10; 896.77±85.88msec in moderately active people with PAL value of 1.62±0.12 and 889.45±68.71 msec in heavily active people with PAL value of 1.86±0.08 with a range of PCT being 773msec to 1147msec (Graph 1), the mean value of PCT being predicted as 814 msec by Hamilton et al in 1983(15). When a statistical fitment is drawn through linear regression analysis, a negative linear relation is obtained with R² value of 0.193 with a b-value=0. This shows a steady decrease of PCT with the increase of PAL i.e. decrease in parasympathetic activity in the eye (Graph 2). We did not obtain a significant difference in physical activity in the age range as we expected. We got an R² value of 0.048 with negative relation which is statistically not very significant in the age range of 18-50 years (Graph 3).

Limitation of the study: This study did not include the sympathetic activity. Therefore, evaluation of the sympathetic activity in the eye in different activity

Fig. 1: The graph shows the true values of PAL and PCT of thirty subjects.

Fig. 2: A graph of statistical fitment is carried out through linear regression analysis to establish existence of negative linear relation between PAL and PCT in all three groups namely sedentary (962.00±105.72 msec), moderately active (896.77±85.88 msec) and heavily active (889.45±68.71 msec).
level needs to be done in order to assess the response of both sympathetic and parasympathetic influence with regards to function of iris.

Conclusion

Our study of noninvasive procedure of finding PCT in various activity levels can promote physical activity. In conclusion, the present finding demonstrate that in physical inactivity, the ocular parasympathetic tone is decreased and there is an enhanced tone in more physically active people having higher PAL value and this increase follows a steady rate supported by data for the first time in Indian males.

Both PCT and PAQ are noninvasive and can be performed in individual without any risk. As this result is corroborating the finding of cardiac parasympathetic tone, measurement of pupil cycle time can be tested as parasympathetic alteration in the eye in physically active people and sedentary people although further study is required to compare both of them in these particular conditions in larger population.

Acknowledgements

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