Isokinetic Muscular Performance in Adolescents - the Effect of Programmed Physical Training

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Summary (Executive)

Since isokinetic evaluation was introduced in the late 1960's (Hislop & Perrine, 1967), numerous reports studying the effect of physical training on muscular performance in adult population have been well documented. In the recent decade, sport scientists become aware of those effects upon adolescence when early identification and training of young athletes for elite performance turn out as a main trend. In sports like tennis and gymnastics, screening of potential athletes start at the age from 7 to 10. Normative data is significant to indicate the potentiality and trainability of a young athlete. In addition, it may render important clinical implication for the planning of both habilitation and rehabilitation programmes for the population. The present study is designed to investigate the effect of programmed physical training on isokinetic muscular characteristics of the junior secondary school students in Hong Kong. The information so collected will also found the data bank for the isokinetic profiles of the local adolescents for further study.

The study finds that programmed physical training is not significantly correlated with muscular improvement during adolescence. It is very apparent an "age effect" constitutes the validity though a minimum average exercise duration of 6 hours per week is advisable to ignite the enhancement. Moreover, no significant correlation supports positive effect of physical training upon the onset of fatigue. When gender is taken into consideration, muscular improvements of male adolescents are more significantly correlated with programmed physical training ($p \leq 0.05$). Medical implication suggests that acute or chronic knee problems will increase among the Hong Kong adolescents if no concerted effort is tailored to maintain a normal range of the Hamstrings:Quadriceps (H:Q) ratio during the pubescent development.

Isokinetic Muscular Performance in Adolescents - the effect of Programmed Physical Training

Summary (layman)

Isokinetic evaluation is an objective way assessing muscular performances. Since the late 1960's, it has been widely used to measure the correlation between physical training and muscular characteristics including muscular strength, power, or fatigue. Although studies have been concentrated among the adult population, trend is now shifting to younger age. Sport scientists become aware of physical training effects upon muscular performances for early identification and screening of young athletes for elite training. In sports like tennis and gymnastics, screening of potential athletes start at the age from 7 to 10. Normative data is significant to indicate the potentiality and trainability of a young athlete. In addition, it may render important clinical implication for the planning of both habilitation and rehabilitation programmes for the population. The present study is designed to investigate the effect of programmed physical training on isokinetic muscular characteristics of the junior secondary school students in Hong Kong. The information so collected will also found the data bank for the isokinetic profiles of the local adolescents for further study.

The study finds that muscular improvements during adolescence are primarily not the result of programmed physical training but an "age effect" so that an older adolescent will be stronger than a younger regardless of any physical training involved. Regular training does neither affect any fatigue characteristics during adolescence. While programmed training renders minimal effect upon muscular development among the female subjects, the male counterparts does exhibit a more significant response. Medical implication suggests that knee problems will increase among the Hong Kong adolescents if no concerted effort is tailored to train the back thigh muscles during the pubescent development.

Isokinetic Muscular Performance in Adolescents - the effect of Programmed Physical Training

Final Report

Section I Background

Isokinetic evaluation is an accurate quantitative and objective measure on muscular performance (Molnar & Alexander, 1973). Since the introduction of the isokinetic exercise in the late 1960's (Hislop & Perrine, 1967), there have been numerous reports studied in this area. However, most of the published research are related to the adult population. In addition, early device was designed to suit only the adult size so that isokinetic studies on adolescent have been very limited.

Among the adolescent studies, contradictory conclusions have been presented. Sewall and Micheli (1986) found that proper progressive exercise programs were effective to yield significant gains in muscular strength in early adolescence. This was affirmed by Pfeiffer and Francis (1986) when they performed programmed tests to the prepubescent, pubescent, and postpubescent males. Adolescent athletes were studied by Tabin, Gregg, and Bonci (1985) who concluded that lean body weight correlated best with maximal torque development. However, these finales were argued by Housh, Johnson, Hughes, Housh, Hughes, Fry, Kenney, and Cisar (1988). Although they did not deny the effect of physical training to muscular performance, they believed an "age effect" existed and stimulated the changes in fat-free weight and so contributed more significantly to the muscular strength development. The effect was further interpreted as a consequence of natural anthropometric growth by Zauner, Maksud, and Melichna (1989): as human grew from the age of 6, muscle fiber thickness increased till the age of 18 which accounted for the increase in lean body mass during adolescence.

This study focuses on the significance of programmed physical training on the muscular performance in adolescent in Hong Kong. The muscular strength, muscular power, fatigue index, and Hamstrings:Quadriceps (H:Q) ratio will be measured upon the knee flexion and extension of both the dominant and non-dominant legs at the speed of 60^0 and 180^0/s by using the Cybex II$^+$ dynamometer. The comparison between the Arts and Physical Education group and male and female performance will be analyzed by using the t-test and Mann-Whitney V - Wilcoxon Rank Sum W test; while the oneway ANOVA, Kruskal-Wallis oneway ANOVA, and the Pearson Product Correlation will be used to analogue the significance of exercise duration to isokinetic performance.

Section II Methodology

Phase I Recruitment of Subjects

The subjects were recruited from the Hong Kong Jockey Club Ti-I College which provides unique curriculum to secondary school students. Students are either streamed in Physical Education (P.E.) or Arts groups when they enter the school. P.E. students receive 8x35 minutes of programmed physical activity class a cycle (a cycle consists 6 day-counts though students attend school 5 days a week). The Arts counterparts, on the other hand, undergo 2x35 minutes programmed physical classes a cycle.

Phase II Isokinetic Testing

Two isokinetic tests performed at 60^0 and 180^0/s on the lower extremities were administered. The first one was conducted at the end of the 1992 academic year when the subjects entered the school as Form I students (mean age = 13.2 ± 0.49). 150 subjects were recruited on voluntary basis out of which 77 were P.E. students and 73 were Arts students. After the second school year in 1993, 126 subjects (mean age = 14.3 ± 0.45) were tested again (57 P.E. and 69 Arts). The missing number was due to the no-shows or invalid data input.

The isokinetic performance of the subjects was compared between that of the P.E. and Arts groups within the corresponding year. Since the students were actively involved in various kinds of extracurricular activities that the college provided, the significance of the overall programmed exercise duration was also correlated with the isokinetic measurements. The exercise duration is classified into 3 categories. Category 1 includes exercise duration ranges from 0-4.9 hour/week. Category 2 ranges from 5-9.9 hour/week. Category 3 includes exercise 10 hours or more per week.

In addition, the difference on the muscular performance between the two tests was contrasted between that of the P.E. and Arts groups and so the overall exercise duration. The natural growth effect upon the adolescent muscular development is expected to be uncovered then. Finally, the isokinetic muscular performances between the two tests were signified.

Phase III Data Interpretation

Discussed in the following two sections.

Section III Results

Most of the results derived from the two tests which are a year apart are analogous. The exercise duration of the Arts students is positively correlated with the students' isokinetic strength and power on both the dominant and non-dominant leg in flexion and extension directions; but there is no significant correlation with the fatigue index ($p \leq 0.05$). For the P.E. group, no significant correlation is found in all the 3 measurements. When all the students are involved in the oneway ANOVA and Kruskal-Wallis ANOVA analysis, significant differences are encountered in all the isokinetic strength and power performances ($p \leq 0.001$).

A significant difference upon the muscular power performance is observed between the P.E. and Arts groups in the two tests ($p \leq 0.05$) both in the parametric and non-parametric analyses. The significance found by the Mann-Whitney analysis is also shown in the strength performance ($p \leq 0.05$) in the two tests except the figure found in the knee extensor of the dominant leg ($p=0.08$) in the latter one. Although there is no significant difference on the fatigue index of the two groups in the second test, there exists a difference in the leg extensor in the former ($p \leq 0.005$).

The isokinetic strength, isokinetic power, and fatigue index are compared between the two tests by the t-test and the Mann-Whitney analysis which reveal identical results. It is found that only the dominant and non-dominant knee extensor show significant difference on the power performance ($p \leq 0.001$) and so does the non-dominant knee extensor upon the strength aspect ($p \leq 0.05$). There, however, does not exists any significant difference on the strength or power upon the flexor and the fatigue index in a year time.

The yearly difference on the muscular strength, muscular power, and fatigue index are contrasted against the exercise duration by means of the oneway ANOVA, Kruskal-Wallis ANOVA, and the Pearson Product Correlation analyses. There is no significant correlation found in all the 3 measurements concurrent with the 3 analyses when all the students are considered. However, the knee extension power and the non-dominant knee flexion power of the Arts group exhibit a significant difference ($p \leq 0.05$). On the other hand, the P.E. group also shows a significant difference upon the non-dominant flexion performance ($p \leq 0.05$).

The t-test and Mann-Whitney analysis are used to measure the difference between the P.E. and Arts students upon their respective growth in strength, power, or recovery ability. Significant difference is only found in the extension strength ($p \leq 0.05$) and the isokinetic power of the dominant flexor ($p \leq 0.05$) from both of the analyses.

The above two tests are also applied to evaluate the effect of regular physical activities upon gender implication. There is no extensive isokinetic measurements found to be significantly different when female subjects are encountered with different exercise involvement. Only the Hamstrings:Quadriceps (H:Q) ratio, flexion strength and flexion power on the dominant limb exhibit significant difference ($p \leq 0.05$) when the girls take less than 5 hours a week to exercise. There is no significant change in any isokinetic performance when the girls are involved with physical activities 5 to less than 10 hours a week. For girls who actively exercise more than 10 hours a week, only the H:Q ratio on the non-dominant leg show a significant change ($p \leq 0.05$).

The male counterparts, on the other hand, does exhibit a stronger relationship between exercise and the isokinetic performances. The more frequent exercise involvement, the more extensive and significant is the relationship found. When boys are involved in regular exercise less than 5 hours a week, significant changes are found in extension strength on the non-dominant leg and the H:Q ratio ($p \leq 0.05$) of the same side. Whereas boys who take more than 5 hours a week in exercise, exhibit significant enhancements in the extension strength, extension power, and the H:Q ratio all on both bilateral sides. In addition, a more significant relationship is found when the boys are involved more frequent in regular exercise. For exercise done between 5 to less than 10 hours a week, the significant level found is $p \leq 0.05$; whilst that done more than 10 hours a week, the level is $p \leq 0.005$.

92/93	Dominant Extension	Non-dominant Extension	Dominant Flexion	Non-dominant Flexion
P.E.	0.081/0.950	0.128/0.815	0.947/0.781	0.721/0.253
Arts	0.000/0.000	0.000/0.000	0.000/0.000	0.000/0.000

Table 1: Correlation Coefficients upon the Muscular Strength and Exercise Duration Compared between the P.E. and Arts students

92/93	Dominant Extension	Non-dominant Extension	Dominant Flexion	Non-dominant Flexion
P.E.	0.309/0.776	0.286/0.858	0.466/0.307	0.860/0.252
Arts	0.000/0.000	0.000/0.000	0.000/0.000	0.000/0.000

Table 2 : Correlation Coefficients upon the Muscular Power and Exercise Duration Compared between the P.E. and Arts students

Section IV Discussion

When the Cybex tests were administered at two points of time, i.e. the end of the first and second academic year, most of the results (90%) obtained are consistent. This is justified for the indication that the test profile shown from the two tests can be a reliable prediction of adolescent isokinetic performance.

It is interesting to find that though the exercise duration is positively correlated with the adolescent muscular strength and power when measuring within all the subjects or the Arts group, the findings is not identical for the P.E. students. There is no significant correlation between the exercise duration and the muscular strength or power. This implies the amount of duration affects the adolescent's muscular performances. The means of the exercise duration of the Arts group in the first and second test are respectively 4.09 and 4.50 hour per week while those of all the subjects are respectively 6.71 and 6.79 hr/wk. For the P.E. students, they are 9.20 and 9.57 hr/wk accordingly. The gap between 6.79 and 9.20 hr/wk turns out to be the critical region for the determination of the maximum amount of exercise that an adolescent requires to efficiently enhance his/her muscular strength or power. Nevertheless, a weekly programmed physical training lasts for 6 hours is effective enough to improve the muscular performances in adolescence.

The muscular power of the P.E. subjects are significantly higher than that of the Arts students, which is expected as a result of the amount of exercise involved. However, the dominant knee extensor shows no significant difference in the strength performance ($p=0.08$). The reliability of it requires further investigation as there still exists gray area. The fact is profounded by the findings of the other strength results which show significant difference between the two groups. On the other hand, the inconsistency about the endurance performance on the knee extension bids for longitudinal study.

When all the subjects are compared upon their respective muscular performances in a year time, significant differences are found in extension power and the extension strength which happen only on the non-dominant side. There is no significant increase on the hamstring power or strength. The possible justification for the phenomenon is that sport movements entail mostly on the extension motion of the lower extremity. Then unless training program is designated to train the flexor muscle, the H:Q ratio is expected to decrease during a non-inactive adolescence ($p\leq0.01$).

The effect of programmed exercise duration on the growth of muscular performances during adolescence is encountered through the analysis of the contrariety of the measurements in the two tests. No significant correlation is found in all the 3 aspects of performance ($p=<0.05$). That is the longitudinal

improvement in muscular strength, power, or endurance do not depend on the amount of exercise duration in adolescence. The growth is basically a natural physiological development in human described as the "age effect" by Housh et.al. (1988). There do exist some significant correlations between the less active subject group or less active muscle group with the programmed exercise duration. However, the correlative implication is arguable because the incident may due to the original inactivity involved. Future scrutiny is decisive for the confirmation of the argument.

Controversial arises when subjects are grouped according to their major studies i.e., P.E. and Arts. The difference between the P.E. and Arts group is significant considering the extension strength and the flexion power of the dominant leg ($p \leq 0.05$). This indicates that the amount of programmed physical activities (mean duration of P.E. = 9.38 hr/wk, mean duration of Arts = 4.29 hr/wk) affects some of the muscular performances across the age group.

Female adolescents are found to be minimally affected by regular physical training. There exists no consistent significant difference upon the isokinetic performances over the two-year period when they are exposed to different exercise duration. The only exception is the H:Q ratio on the non-dominant limb which exhibits a significant difference when the subjects are either exposed to regular exercise less than 5 hours or more than 10 hours a week ($p \leq 0.05$). However, the indefinitive observation acquires further inquisition.

Quite a distinct picture is observed from the results of the male adolescents. Not only do the boys' isokinetic performances are affected by regular physical exercise more extensively which include both extension strength and power and the H:Q ratio of both the dominant and non-dominant limbs, but the level of correlational significance increases as the exercise duration increases (Table 3).

Exercise Duration (hr/wk)	Isokinetic Performances	Level of Significance
0 - 4.9	non-dominant limb extension strength non-dominant limb H:Q ratio dominant limb extension Fatigue Index	$p \leq 0.05$
5 - 9.9	dominant limb extension strength non-dominant limb extension strength dominant limb extension power non-dominant limb extension power dominant limb H:Q ratio non-dominant limb H:Q ratio	$p \leq 0.05$
≥ 10	dominant limb extension strength non-dominant limb extension strength dominant limb extension power non-dominant limb extension power dominant limb H:Q ratio non-dominant limb H:Q ratio	$p \leq 0.005$

Table 3: Significant effect of regular physical training on the isokinetic performances in male adolescence

Section V Conclusion

The importance of anthropometric development, the age growth, upon the enhancement in muscular strength and power during adolescence is signified in this study. The increase in the recruitment units of muscle fiber prevails in this particular period of growth. It is the primary cause why a post-pubescent to be stronger than a pubescent regardless of other physical or physiological similarities. A reasonable conclusion is that no matter what quantity or quality of physical exercise is induced to an adolescent, he/she will gain in muscular strength and power from year to year. Then a quest is raised on the validity of physical training to an adolescent's growth.

From this study, we find that age is not the only justified cause for the physical growth in adolescence. A certain amount of regular programmed physical exercise is necessary for the enhancement over the natural physical growth. Although the minimum quantity of exercise is not determined in this study, yet an average of 4 hr/wk is notably enough to impel the enhancement. On the other hand, the proportion is not infinitively correlated. A minimum average exercise duration of 6 hr/wk is effective enough to produce maximum muscular improvement. We suggest either 3 sessions of 2 hours or 6 sessions of 1 hour each in a week for muscular training is already effectual to inflate an adolescent's strength and power. Since quite a number of the P.E. subjects are junior squads in Hong Kong, it is reasonable to predict that 6 to 9 hr/wk is the range of muscular training duration necessary to maximize the muscular improvement.

There is no consistent correlation between the exercise duration and the fatigue index. The rate of recruitment on muscle fiber does not necessarily depend on the amount of physical activity that an adolescent engages in. For example, an inactive pubescent may be able to sustain an isometric contraction as long as a regularly trained pubescent. However, the phenomenon prompts for further controlled test for the uncovery.

Although a different implication is found between the female and male adolescents when minimal significant isokinetic performance difference found in the former whilst significant differences exist in the latter, the conclusion should not be necessarily aversive to either of the gender. The subjects are so chosen that they are at similar age i.e., all Form 1 students in the first year and Form 2 in the second year (Table 4). However, growth profiles of same aged female and male adolescents are unlike. It is generally accepted that girls mature earlier. Then a 13-year-old girl is physically more mature than a same-aged counterparts. To isolate a particular period of time testing the effect of regular physical training on the isokinetic performances in adolescence of the both genders does not necessarily render similar results or that the rationality can be fairly justified.

Further studies should concentrate at the time of growth period rather than the age of the subjects. Nevertheless, the present study finds a significant enhancement upon isokinetic performances as a result of regular physical training in the male adolescence.

	Male	Female	Total
1992	13.2±0.49	13.2±0.48	13.2±0.49
1993	14.3±0.48	14.2±0.42	14.3±0.45

Table 4: Mean Ages of the Male and Female Subjects in Year 1992 and 1993

A medical problem pops out concurrent with the above physical findings. Knee injuries are expected to increase among the adolescents in Hong Kong if no intentional exercise designed to work on the flexor muscle. As the study reviews, only the extensor muscle benefits significantly from physical activities. This decreases the H:Q ratio as time goes on so that the knee joint is constantly stressed by the stronger muscle. Unnecessary chronic or acute injuries are then possibly induced. We suggest programmed physical activities provided to adolescent should involve the training of the hamstring muscle regularly. Prevention always proceeds cure.

Section VI Appendix

(see attached)

Appendix I

Isokinetic Test Protocol

AIM

To test muscular strength, power, and endurance of knee extensor and flexor

1. Subjects are required to warmup before the test, which includes jogging and stretching for at least 5 minutes.

2. The non-dominant leg is tested before the dominant first upon the speed of 60°/s then 180°/s.

3. Upon the 60°/s testing, 5 to 7 times of practices are performed before data is collected to let the subject to get used to the speed. 5 testing data are then recorded.

4. Subjects rest for one minute.

5. 5 to 7 practices are also performed at the 180°/s test. This time subjects are tested for one minute. All the data are recorded.

6. Subjects rest for 2 minutes to be tested on the dominant side following the procedure (3) to (5).

7. Test finishes.

Appendix II

Ti-I College Student Assessment Form

Date: ____/____/____
day mth yr

Name: _____

Sex: M / F **Age:** _____

I.D. No.: _____

Dominant Side: Rt. / Lt.

Weight: _____lbs **Height:** _____inch

Group : P.E. / Arts

Major Sports: _____

Level of Sports: ( ) National ( ) School Team
( ) Recreational ( ) Others: _____

Frequency of Sports: _____ hours per week
(include training and P.E. lessons)

Cybex Testing

	60°/s	80°/s
Rt. Knee		
Lt. Knee		

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