The effects of visual skills on Rhythmic Gymnastics*

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Abstract

Vision plays an important role in all sports, but has often been neglected when evaluating the performance of athletes. Rhythmic Gymnastics is a dynamic and compelling sport for girls that challenge body and mind. It is a relatively new Olympic sport that requires performance according to a set standard. The goals of this study were to identify the visual skills important to rhythmic gymnasts and to explore whether these skills could be improved by means of an intervention programme. This study further aims to provide sport specific visual performance standards to the gymnasts. Little research is available connecting vision to this sport and it was seen as a good opportunity to make a difference. After testing the visual skills of a sample of 62 rhythmic gymnasts (divided randomly into two comparable groups of 32 for the experimental group and 30 for control group) the experimental group followed a sports specific intervention programme while the control group adhered to their regular training schedule. The visual skills trained by the intervention programme were re-tested on both the experimental and control groups of gymnasts. The results obtained from the post-intervention measurements were analyzed and compared to the original data obtained from the pre-intervention measurements of both the groups of gymnasts. Results from competitions were obtained and compared to establish the effect of the intervention programme. It is concluded that the software skills of the visual system plays an important role in the sport of rhythmic gymnastics. These skills can be improved by implementing a sustainable visual training programme for the training of rhythmic gymnasts.

Key words: sports vision, rhythmic gymnastics, visual skills.

Introduction

Sports vision is defined as the study of visual abilities required in competitive and recreational sports, and the development of visual strategies to improve performance, consistency, accuracy and stamina of the visual system needed.[1] It deals mainly with four cornerstones, which are corrective eyewear, protective eyewear, visual skills and visual performance enhancement.

Vision and visual skills play an important role in most sports.[2] According to Venter and Ferreira[15] a skill is a specialized movement pattern and can be learned. It can be acquired through practice and competition. Visual skills refer to any skill that involves the eye, and include the testing and evaluation

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thereof.[3] Specific sports require specific visual skills, but the skills that are generally tested in sports vision include general ocular health, visual acuity, contrast sensitivity, colour discrimination, stereopsis, fusion and accommodative flexibility, visual adjustability and visualization, as well as eye-hand and eye-body coordination, central-peripheral awareness and visual response time.

General Ocular Health includes the health of the eye itself, the ocular adnexia and the visual pathways.[4] Good eye-health is mandatory for high sporting performance.[5] Inefficient visual abilities may limit competitive potential or may even be responsible for inconsistencies in sporting performance under specific circumstances or times. An example of such circumstances is when an athlete is fatigued or under extreme competitive stress.[6]

Static Visual Acuity is the ability to resolve various sizes of letters or objects at various distances from the observer.[4] It can also be defined as the clarity of eyesight.[7] Acuity with both eyes together should be better than in each eye individually. Deficits in this resolving ability can cause an athlete to be unable to see and recognize small objects clearly and rapidly.[4]

Contrast sensitivity deals with the ability of an athlete to discriminate detail in his/her field of view,[4] or to detect border contrast.[5] It is also a measure of visual sensitivity to subtle differences in black-white contrast.[7] The measurements indicate the least amount of contrast required to detect a visual stimulus. Deficits in this ability can make it difficult for an athlete to 'pick-up' and follow any object.[4] An abnormal contrast sensitivity score may be related to an uncorrected refractive error or diseases such as glaucoma, cataracts and diabetic retinopathy.[3]

Under photopic (light) conditions an athlete's visual system has a highly developed sense to discriminate millions of different colours. For absolute judgments, however, only about 30 colours can be identified reliably as stated by Bishop and Crook[5] (1961). Having good *colour vision* means that an athlete can rapidly (and accurately) recognize the various colours found in the visual spectrum.[4] Colour vision is a function of the cones in the retina and therefore an athlete's ability to perceive colours is drastically reduced under scotopic (dark) conditions.[5]

Having good *depth perception (stereopsis)* means that an athlete will be able to rapidly and accurately utilize the fused images. This is necessary to judge distances and spatial relationships from one object/place to another during sporting activities.[4] It is important to note that although the terms depth perception and stereopsis are used interchangeably, they are not entirely the same. Should an athlete have only one functional eye, he/she will still be able to achieve depth perception. Stereopsis, on the other hand, requires binocular vision and therefore the use of both functional eyes. It is difficult to estimate the specific role of stereopsis in dynamic sports environments, since depth perception constantly changes with changes in movement of both an athlete and the object relevant to the specific sport.[8] Binocular abilities are necessary for directional properties of vision, including depth perception. Studies concerning these ideas seem to indicate that athletes do indeed have better depth judgments.[2]

Focus flexibility or accommodation can be defined as an ability that allows an athlete to rapidly change focus from on point in space to another without excess effort. It also tells an athlete whether the target is coming closer or retreating further away.[4, 9] Deficits may slow down the ability to quickly and accurately follow an incoming/outgoing object. Clarity of objects is also influenced by accommodation.[4, 7] Accommodation is mainly relevant at distances closer than one metre from the emmetropic athlete, and therefore its importance in certain sports is debatable, as stated by Ludeke and Ferreira (2003)[8].

Fusion flexibility or binocularity aim to rapidly and accurately fuse the two images (each from one of an athlete's two eyes) into a single image. It also functions to help the eyes work as a team to maintain a single image in all directions of gaze.[4] Deficits may generally lower an athlete's performance but more specifically, cause an athlete to experience diplopia or double vision, have difficulty to accurately follow objects and humans in his/her field of view, and to misjudge distances and directions.[7] Accommodation and vergence takes place when an athlete is looking from a distant object to a near object or the other way around.[7]

Central-peripheral awareness refers to the ability of an athlete to pay attention to what is happening in front of him/her, but at the same time be aware of what is going on to his/her sides without having to move his/her eyes from the object of regard.[4] If this skill is deficient an athlete may lose objects or people to his/her sides and often be distracted from where he/she is looking by peripheral events.[10] It is important to note that there is a significant difference between the visual skill central-peripheral awareness and the general optometric term of visual fields. The total visual field of an athlete is a function of the healthy anatomy of the eyes whereas central-peripheral awareness is a function of visual perception and evaluates the athlete's ability to respond to central and peripheral stimuli without moving his/her head.[5] An athlete can have normal visual fields to all directions but show poor central-peripheral awareness in sporting conditions. Peripheral vision together with eye-body coordination, give an athlete the ability to move his/her body gracefully through space, and helps to maintain good posture and balance as well as orientation to the activity.[9]

Eye-hand coordination involves the integration of the eyes and the hands as a unit in a particular happening. The information as detected by the eyes and vision is processed by the brain and the hands are then used to utilize a reaction.[4] It is most often regarded as a measure of an athlete's ability to institute a quick and accurate response to a stimulus. It may be divided into two parts of which the pro-active part is initiated by the athlete self. The re-active type is seen as the response by the athlete to this pro-action.[5]

Eye-body coordination refers to this integration between the eyes and the body. Here the whole body or at least parts thereof is involved in the reaction on the visual stimulation.[4] It requires an integration of the senses of vision, equilibrium and proprioception. According to Davis *et al*[5] (1986) these are the three most important senses involved in the performance of motor skills. Eye-body coordination is also a measure of the quality of the integration of the receptor, perceptual and effector mechanisms. *Eye-hand-body coordination* deals with the integration of all these structures as a unit.[4, 6] The eyes must lead and guide the motor system of the hands or body. Deficits can affect all levels of performance that require movement by an athlete.[10]

Reaction time can be defined as the time taken from the detection of a stimulus to the initiation of an appropriate movement in response to that stimulus.[11] Visual reaction time is the time required to perceive and then respond to visual stimulation. This includes an athlete's ability to utilize auditory information to assist any visual stimulation.[4] Deficits can cause a slow response to actions occurring during sporting activities. *Response time* is defined as the total time necessary to process the visual information and complete the motor response sequence.[7]

Speed of reaction (and response) to visual information is important to perform well in any sport where motor responses must be precisely timed.[6] Visual response time is similar to eye-hand coordination as the visual system guides a motor response. In this case, however, one is more interested in the speed of the response to a visual stimulus.[10] The terms reaction time and response time is often used interchangeably. Response time is the better term to use since we measure the time necessary for the initiation of the response under the condition that the subject has been instructed to respond as quickly as possible.[7] This should be the term to be used by all researchers in the future.

Visual adjustability means having a visual system that is flexible enough to rapidly adjust and guide the body's motor responses quickly and accurately while surrounding or environmental changes are taking place.[4] It can also be defined as the art of being tuned into body responses even though the demands may vary (Planer, 1994).[5] In an environment where things change quickly (for example during ball games like rugby[49]) it may be crucial for an athlete to react within split seconds. Deficits in this ability can slow the responses of an athlete considerably and make any attempted responses unpredictable and inconsistent.

Visualization means that an athlete can mentally imagine and rehearse a situation, action or response that can or do occur during sporting activities; modify these occurrences to be more efficient and correct; and then be able to use this information during actual sporting performance now and in the future.[4] Deficits can hinder an athlete's correct responses to various situations and will make it difficult to learn from mistakes made by him/her or others during practice or competition. This is an abstract skill – a mental process - and does not actually involve the eye or vision.[10]

Visualization, though often neglected by sports vision practitioners, seems to be an extremely important visual skill when it comes to athletic performance.[4] Lying in bed at night visualizing and rerunning videotapes of their performances in their minds often enhances athlete's future performance by making use of muscle memory. This means that the visual images are collated with movement patterns previously experienced during performance. Jacobson[2] showed that physiologically, a person's muscles (or that of any athlete) showed small detectable amounts of electrical activity associated with movement when that person imagined a specific activity. Athletes can practice their mechanical skills in their mind by visualizing the task beforehand. This can be done at any time, except at the time of the action. Thinking about the mechanics during the action interferes with coordination and grace.[9]

Eye dominancy: The dominant eye is the one that leads the other in fixation or seeing.[13] Coren and Porac (1982) showed that the brain receives visual information about 14 milliseconds faster from the dominant eye than from the non-dominant eye. It is theorised that the body will now react quicker and be in a better position to react.[13]

Buys[3] determined norms for the general visual skills (hardware and software skills) used in sports vision. His norms will be used in this study as a yard stick to evaluate the gymnasts' performance.

It is often assumed that visual abilities are trainable and that this training is transferable to sports performance.[14] Some studies have shown positive results[17] with training, but in contrast to this there are also studies that have shown no positive effects of visual skills training.[15] There is strong evidence to support both of the above arguments. One possibility for the difference in findings is that different testing methods were used in the separate investigations. Standardized testing procedures should be implemented and testing should be separated from training. Standardized measures are used and training of these skills should be made sport specific.[16, 17]

Rhythmic gymnastics is a dynamic and compelling sport for (mostly) girls[18] that challenges body and mind.[19] It is a relatively new Olympic sport that requires performance according to a set standard.[20] Rhythmic gymnasts, like artistic gymnasts astound, entertain and inspire, since they make their particular talents seem simultaneously simple and impossible.[21] This, or any kind of gymnastics for that matter, is an amazing sport for spectators to watch. Furthermore, it is an extraordinary sport to practice as it psychologically gets into your blood and become an integral part of your daily life.[21] It is a graceful, dynamic and captivating sport, associated with sheer beauty, poise and elegance.[22] A certain degree of natural grace, musicality, creativity and rhythmic awareness is needed, together with flexibility and coordination components.[18] Some girls display a more natural talent to the sport than others, also due to the dancing component's need for a sense of rhythm. Rhythmic gymnastics must not be confused with the more familiar artistic gymnastics.[20] Rhythmic gymnastics offers girls who love to dance and at the same time like the competitiveness of a sport, an opportunity to express themselves.[19] These gymnasts use different apparatus (hoop, rope, ball, ribbon and clubs) during their routines.[47]

During a competition, three panels of judges determine each gymnast's overall score. While one panel evaluates the degree of difficulty in each gymnast's routine, another takes a look at the choreography and artistry and the third panel counts the gymnast's mistakes.[23, 24] The three marks are added to give a score out of 30.[23] The more difficult the skill performed, the more likely it is for the technical execution to be excellent and the more likely that it achieves an aesthetic quality.[21] There are automatic deductions for not using the entire carpet or stepping outside the limit.[25]

Gymnastics (rhythmic, artistic, tumbling and trampoline) combines vision and visualization with eye-hand/body coordination and balance in a dynamic setting. Unlike most athletes, a gymnast has to be aware of his/her overall body scheme and the interaction between visual skills and body positioning is critical.[26] Vision and visual skills are therefore just as important in rhythmic gymnastics as in any other sport.[2] Optometry and sports vision can give rhythmic gymnasts the visual edge they need for top performance.[27] According to the researcher's knowledge, no (or at least very little) previous research has been done to investigate the visual skills of rhythmic gymnasts or to evaluate the effect of the enhancement of visual skills on sporting performance, thereby connecting sports vision to rhythmic gymnastics. The need for such a study was therefore confirmed and it was seen as a good opportunity to make a difference in the world of rhythmic gymnastics.

The aims of this study were:

1. to identify which visual skills (hardware versus software skills[50]) are important in the sport of rhythmic gymnastics and
2. to investigate whether those visual skills that are important in rhythmic gymnastics can be improved by means of an intervention programme.

The subjects in this study were rhythmic gymnasts. The terms 'subjects'and 'gymnasts' are both used throughout the text to refer to the girls who participated.

Methodology

The Ethical Committee of the University of Johannesburg gave its approval to go ahead with the study before it was started. A sample of 62 rhythmic gymnasts, ages 6 to 19 participating in levels 1 to 9 (with the exception of level 3), the Junior and Senior Olympic classes and some gymnasts from the Olympic Development Programme (ODP), were invited to participate in this study. Consent forms were sent out to the gymnasts in the sample group prior to the first set of measurements to gain the parents' permission to work with their children. The sample group of 62 gymnasts was divided randomly into two comparable groups of 32 (experimental group) and 30 (control group) gymnasts on the grounds of level and age. Gymnasts in each level were randomly assigned to one of the two groups with the aid of class lists. The difference in ages in each individual level were taken into account by arranging each class list in order from the youngest to the oldest gymnast and assigning every second name to the same group. One group was randomly picked to be the experimental group (those gymnasts that were to follow the intervention programme) and the other was assigned as the control group. A total of 32 gymnasts were selected for the intervention group and 30 for the control group. A bigger group was selected initially to allow for up to 2 gymnasts to withdraw from the study, but to still keep our sample size a minimum of 30 gymnasts in the intervention or experimental and control groups respectively.

The experimental group followed the intervention programme for five weeks, training twice a week while the control group adhered to their regular training schedule. This routine included warm-up, jumps, leaps, turns and their individual and group routines. They received no instruction as to any special intervention-exercises done by the intervention group, though they could see the intervention group training.

An important aspect of scientific research is to find or develop appropriate assessment procedures.[28] The procedures followed to test the sample group of rhythmic gymnasts were in accordance with the general methods used by the Sports Vision Academy of the University of Johannesburg. These methods have been accepted by SISA (Sport Information and Science Agency)[29] as the standard testing methods used to test elite athletes. Advantages of standardized testing conditions are that they are simple and repeatable. Without a shared, standardized core of knowledge, those working with sports vision would not be able to communicate with each other and the impression of sports optometry on the public would be that it is disorganized.[6]

It is important to note that the visual skills were tested under the normal conditions that the gymnasts experience during training and participation in competitions, thus in a realistic environment. It is said that significant hyperopia, as well as myopia and astigmatism should be corrected in athletes.[14, 30] In this study, gymnasts that wear a visual correction (spectacles or contact lenses) and participate in the sport without it, were therefore tested without wearing the correction.

General Ocular Health was evaluated by doing direct ophthalmoscopy on both eyes of each athlete. No abnormalities were found in any of the sample group subjects.

Static Visual Acuity was tested at a distance of 6 metres from a Standard Snellen chart. The monocular and binocular acuity's were taken. The Snellen notation was recorded and converted to logMAR notation. This had to be done for analysis by the STATCON department.

C*olour Discrimination* was tested using the Fansworth D-15 test, also known as the dichotomous test. The test shows red-green and yellow-blue anomalies and is useful to screen for colour deficiencies. After 15 colour discs were shuffled each gymnast had to put them into their pilot in the right order to form a smooth colour sequence. Each disc varied slightly from the previous one in colour and hues. The number of errors made was recorded, and if no errors were made, the skill was ticked off as being correct. There was no time limit and the gymnasts could change the sequence of the discs if they wished to while arranging it in order.

The Functional Acuity Contrast Test was used to test the gymnast's *Contrast Sensitivity* at 3 metres. Contrast Sensitivity can be explained in terms of five horizontal rows (A to E) situated below each other. In each row, nine circles are seen next to each other, each circle representing a different level of contrast sensitivity. Each circle contains a pattern of sinusoidal gratings which slant either to the left or right or may be vertically orientated. These gratings are of varying spatial frequencies and of variable contrast as stated by Charman[5] (1979). From the first circle (on the left hand side of each row) to the ninth circle (on the right hand side of each row), contrast is reduced to the same amount in each row. While binocular, the gymnast had to look binocularly at each row in alphabetical order, therefore from a low spatial frequency in row A to a higher spatial frequency in each row, ending with row E. The different spatial frequencies represented by the rows are: Row A = 1.5 cycles per degree (cpd), Row B = 3 cycles per degree (cpd), Row C = 6 cycles per degree (cpd), Row D = 12 cycles per degree (cpd) and Row E = 18 cycles per degree (cpd). In each row, gymnasts had to identify the direction of the grating in each circle numbered from one to nine and the grating representing the lowest contrast that was correctly identified was recorded. As the brightness and colour of the background areas approach that of the gratings (therefore if the contrast between the background and the gratings lessens), seeing the gratings becomes much more difficult.[5]

Stereopsis was tested by means of the Randot Stereo Test where a gymnast wearing cross-polarized lenses had to correctly identify which of the circles stands out on ten different lines. The booklet was held at arm's length or 40 centimetres and the smallest dot identified as appearing closer to the gymnast was recorded in terms of seconds of arc, as provided by the instruction manual of this test. This describes the angle of the disparity that is present in the specific target at a specific distance. The test varies in difficulty, ranging from 3000 seconds of arc (representing almost no binocularity) to 20 seconds of arc which is the most difficult to distinguish.

To test an athlete's ability to *accommodate* sufficiently, the Academy makes use of plano/ –2.00 flippers at distance (6m) and +2.00/ –2.00 flippers at near (40cm). The gymnasts looked binocularly at the 6/12 Snellen line, on both distance and near VA charts. For distance testing the gymnasts stood at 4 m from the chart and a smaller line equivalent to 6/12 at 6 m was used. Each gymnast had to clear the line which appears noticeably blurred through the first set of lenses. Once it was cleared, the gymnast flipped the flipper over and tried to clear the line once again through the other set of lenses. This was done for 30 seconds. The amount of cycles were noted and multiplied by two to give the amount of cycles cleared in one minute.

Base-in/base-out flippers were used in the same way as above to determine *fusion flexibility*. The flipper consisted of a set of 6-prism dioptre base-in lenses and 12-prism dioptre base out lenses. The gymnasts looked binocularly at the 6/12 Snellen line, on both distance and near VA charts. For distance testing the gymnasts stood at 4 m from the chart and a smaller line equivalent to 6/12 at 6 m was used. Once a gymnast fused the 6/12 Snellen line which appeared noticeably double, the instrument was flipped over and the gymnast tried to clear the lines with the base in the other direction. Gymnasts were continuously motivated to concentrate on fusing the target.

Eye-hand and *Eye-body* coordination as well as *central-peripheral awareness* and *visual response time* were measured by using the Wayne Saccadic Fixator. When testing eye-hand coordination, the instrument was placed at eye level with the gymnast, an arm's length away. The instrument's lights went on randomly for thirty seconds and each light only went off when the gymnast had touched it. The number of lights touched in 30s was recorded. Gymnasts were encouraged to react quickly in order to get better results (more lights touched). Only pro-action time was measured where each light went off only when the gymnasts had touched it.

A balance board was connected to the instrument and placed on the ground in front of the instrument when eye-body coordination was tested. The board had four on/off switches underneath its bottom and was raised by a 5 cm wooden block serving as a pivot point. The Wayne Saccadic's lights went on randomly at the 3, 6, 9 and 12 o'clock positions and the gymnasts were expected to shift their balance on the board in order to press the board down to correspond to the light appearing. Gymnasts were not allowed to move their feet but only use their balance to manipulate the board.

Central-peripheral awareness was tested in the same way as eye-hand coordination except that the lights went on centrally every second time, followed by a light anywhere in the periphery. The gymnast had to constantly fixate on the central light, and therefore saw the peripheral lights only with her peripheral vision. The gymnast was allowed to use both hands to touch the lights. Once again, 30 seconds were allowed for the test.

The horizontal visual response time of the left and right hands of each gymnast was tested by having them push the lights going on alternatively in the 3 and 9 o'clock positions on the Wayne Saccadic. The quickest time in moving from one position to the next (giving the gymnast about five to seven tries) was recorded.

Yoked prisms of 20 prism diopters each were used to test *visual adjustability*. A gymnast had to hit a target (a cross drawn on paper and stuck to a wall in the training area) with a tennis ball while wearing the prisms with the bases in four different directions while standing 3 m away. Through each set of prisms, the image of the cross was displaced towards the apex of the prism, therefore in the opposite direction of the base. The number of times she had to throw the ball before hitting the cross was counted and recorded. No more than 15 throws with the prisms in each direction were allowed.

Visualization was tested by using the Getman Manupilation Test which consists of four simple figures. These are an L-shape, a half circle, a triangle and a T-shape. The athlete had to answer three questions for each figure. They are: What would the figure look like if you were to see it from the back/ behind, if you flip it upside down and if you flip it upside down and look at it from the back/ behind. A card with four possible answers to each question was given to the gymnast to choose from. The amount of correct answers out of 12 was recorded.

Dominancy was determined in the following ways: A gymnast was asked with which hand she wrote with to determine hand dominancy and pushed unexpectedly from the back to see what foot could be taken as the dominant one. Eye dominancy was tested by asking a gymnast to hold her fingers in a triangle form in front of her face, an arms length away. She then had to look through this triangle at a distant target. The eye with which she could still see the target when closing the other eye, was the dominant eye. This is called the Sighting test.

STATCON (the Statistical Department at the University of Johannesburg) assisted in the statistical analysis of the results. The programme SPSS (Statistical package for the Social Sciences) for Windows, edition 14, was used. After analyzing the first set of results and concluding that the intervention and control groups were comparable by means of tests of normality, an intervention programme was introduced to the experimental group of gymnasts. The skills eye-hand and eye-body coordination, central-peripheral awareness, visual response time, visual adjustability and visualization are known as software skills of the visual system.[28] As concluded by Ferreira (2002)[28], Langhout (2006)[31] Nel (2006)[32] and Van Zyl (2006)[12] the hardware skills of the visual system do not differ between athletes and the normal population. The differences are found only in the software skills and these skills were therefore identified as being important in the sport of rhythmic gymnastics. Fusion flexibility falls under the category of hardware skills. Since some sports optometrists advocate the development of six meter vergence ranges for athletes as a means of general enhancement of visual function,[6] it was decided that this skill would also be trained to investigate its importance in rhythmic gymnastics. The intervention programme was therefore designed to train eye-hand and eye- body coordination, central-peripheral awareness, visual response time, fusion flexibility, visualization and visual adjustability. The programme was designed to be sport specific. The difficulty of the exercises also varied in such a way that rhythmic gymnastics of different ages/levels could participate. The intervention programme is available from the researcher on request. A control group consisting of gymnasts of matching ages/levels to those gymnasts following the programme continued with their normal training routine.

Only those skills trained by the intervention programme were re-tested on all gymnasts. The set of results obtained from the post-intervention measurements were analyzed and compared to the original data obtained from the pre-intervention measurements of both the experimental and control groups.

Results

The results were separated into two different sections. Section A deals with the hardware skills of the visual system and section B the with the software skills and fusion flexibility.

Section A:

The Mann-Whitney U test showed no statistical differences between the results from the experimental and control groups, with regard to the initial measurements of the hardware skills.

Section B:

The skills reported for here are fusion flexibility at near and fusion flexibility at distance, and the software skills central-peripheral awareness, eye-hand coordination, eye-body coordination, visual response time (right eye), visual response time (left eye), visual adjustability (base-up), visual adjustability (base-down), visual adjustability (base-left), visual adjustability (base-right), visualization. The results for these skills will be represented below by means of figures 1-12.

All the figures following in this section were done in the same format to ensure uniformity and to allow the reader to compare the results represented in them with each other. The *x*-axis of each figure shows the average values for that specific visual skill, with the span of the standard deviation around it for both the experimental and control groups. The *y*-axis shows the units of the specific skill in terms of a 95% confidence interval. Each figure contains the mean value for the results of the visual skill of the experimental and control groups respectively. The norms as determined by Buys[3] are shown on each figure in the form of coloured lines representing the categories superior (blue), average (green) and need immediate attention (red).

The graph illustrating the results for visualization were put next to the graph illustrating the results for central-peripheral awareness, rather than after visual adjustability, for the purpose of presenting the graphs in an orderly format.

Figure 1: Fusion Flexibility - near

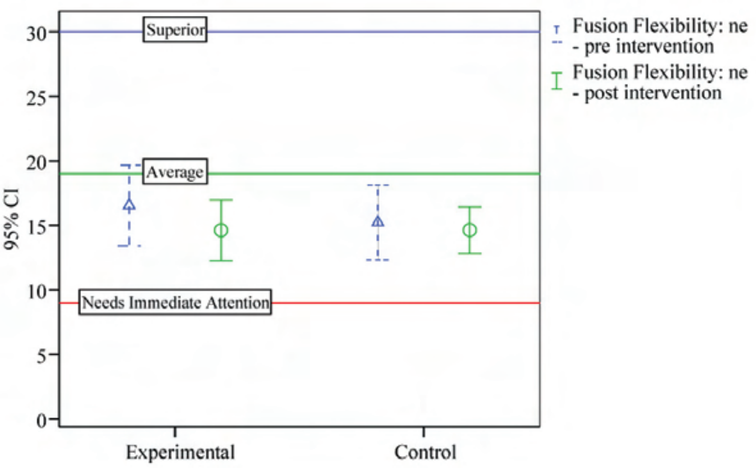


Figure 2: Fusion Flexibility - distance

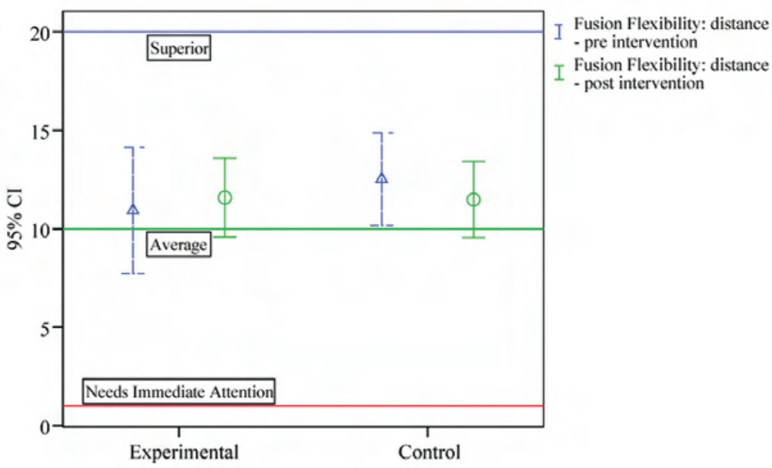


Figure 3: Central - Peripheral Awareness

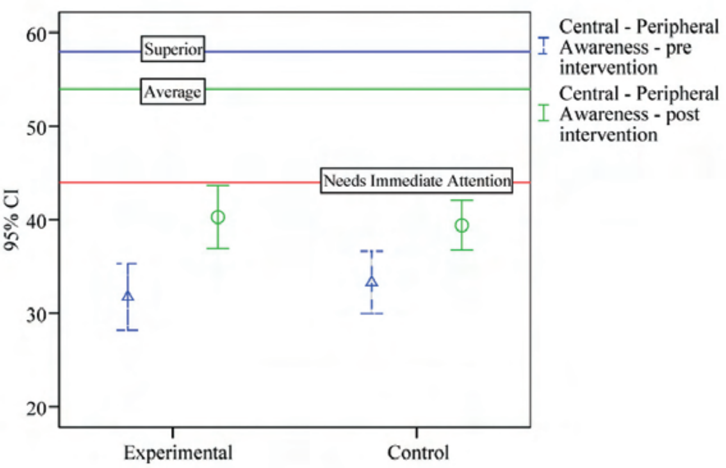


Figure 4: Visualization

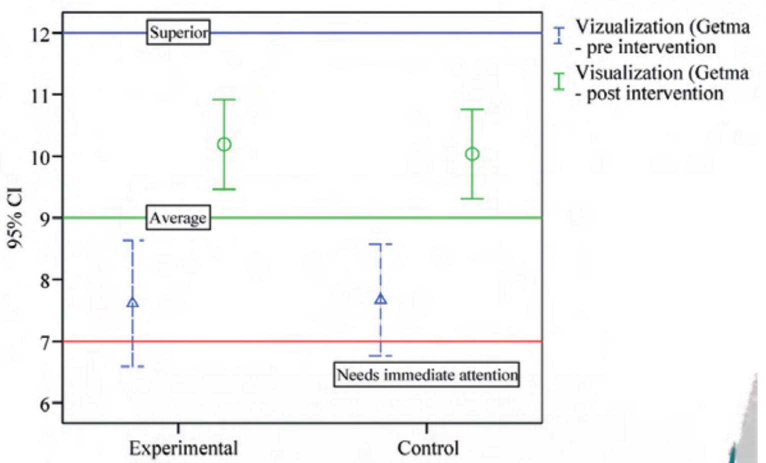


Figure 5: Eye-hand Coordination

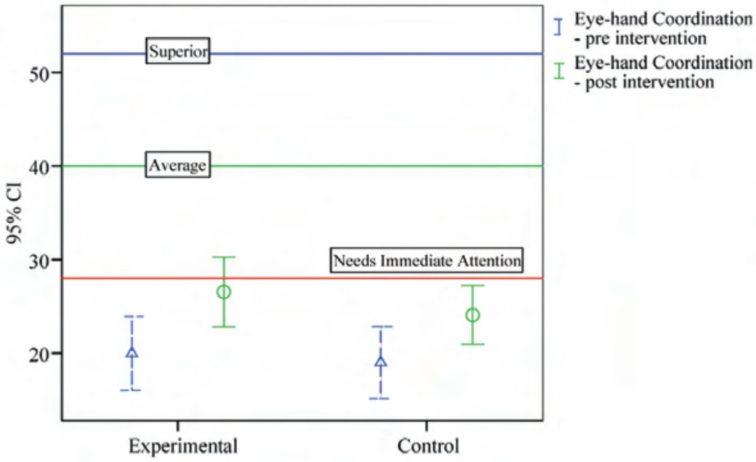


Figure 6: Eye-body Coordination

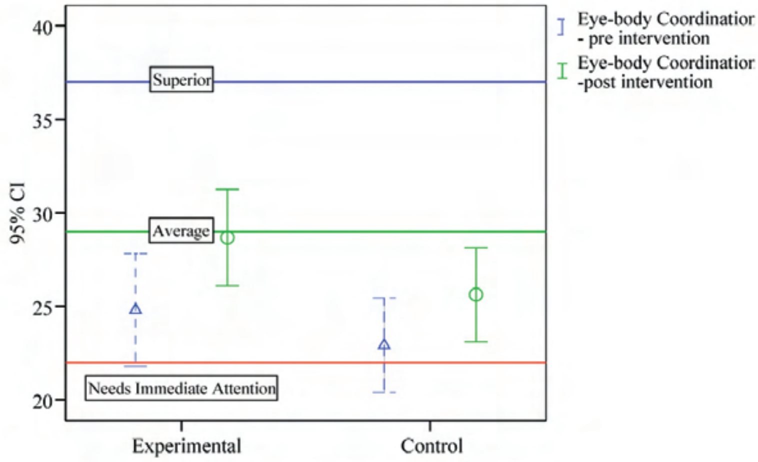


Figure 7: Visual Reaction Time - Right

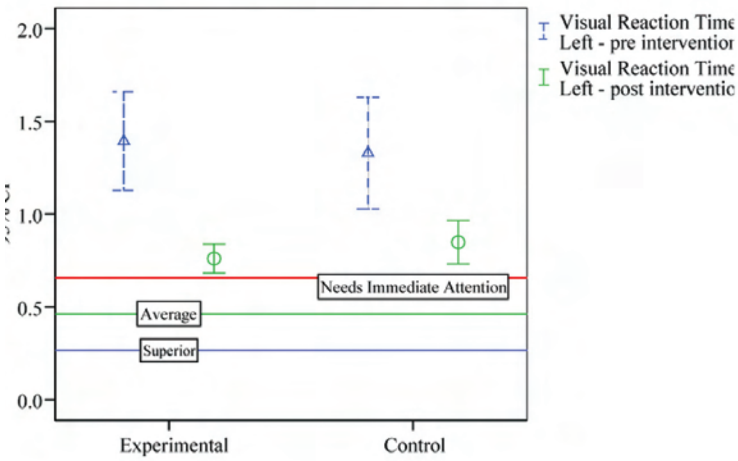


Figure 8: Visual Reaction Time - Left

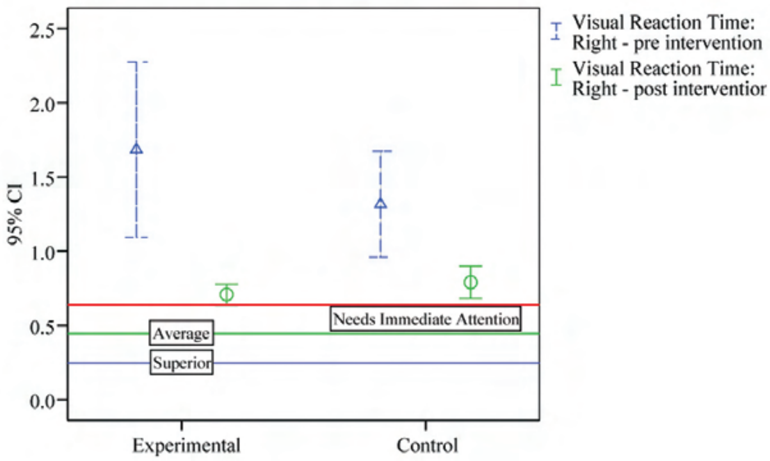


Figure 9: Visual Adjustability - Base Up

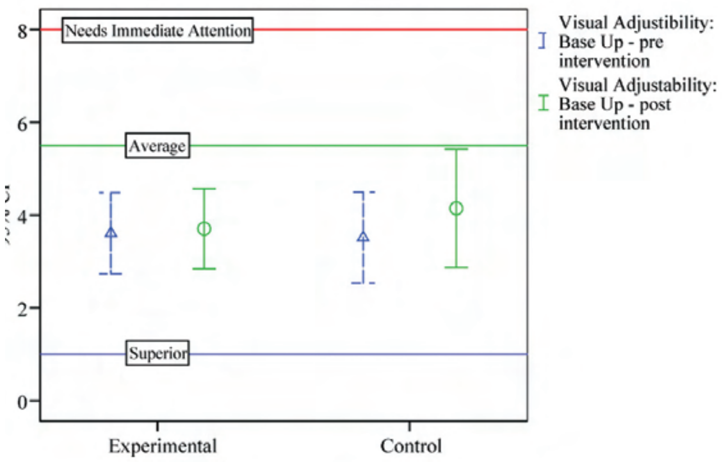


Figure 10: Visual Adjustability - Base Down

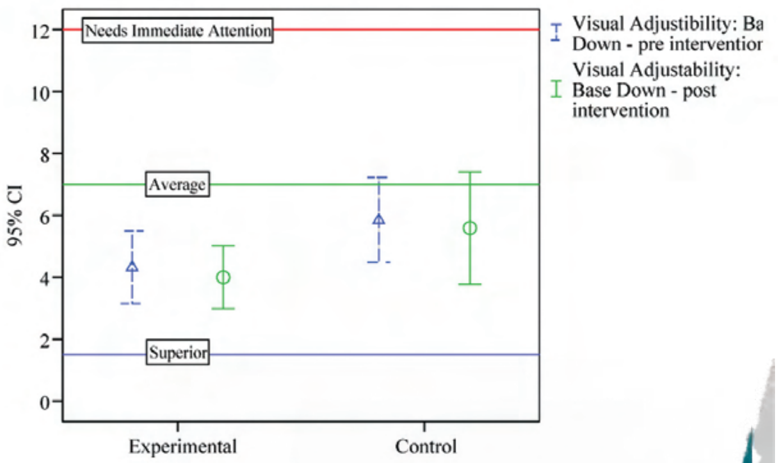


Figure 11: Visual Adjustability - Base Left

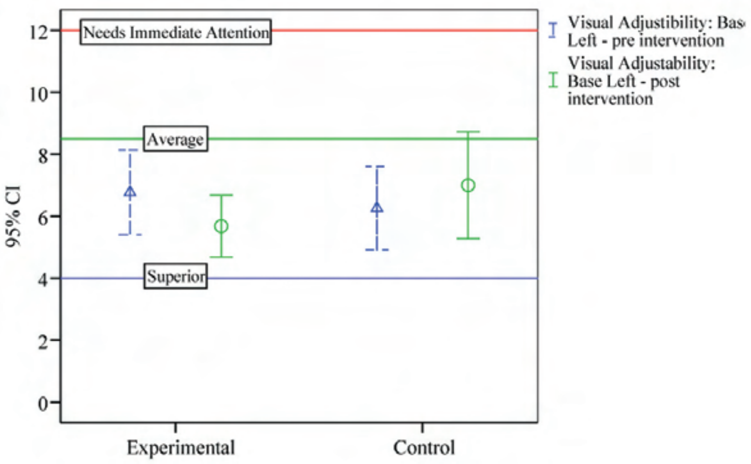
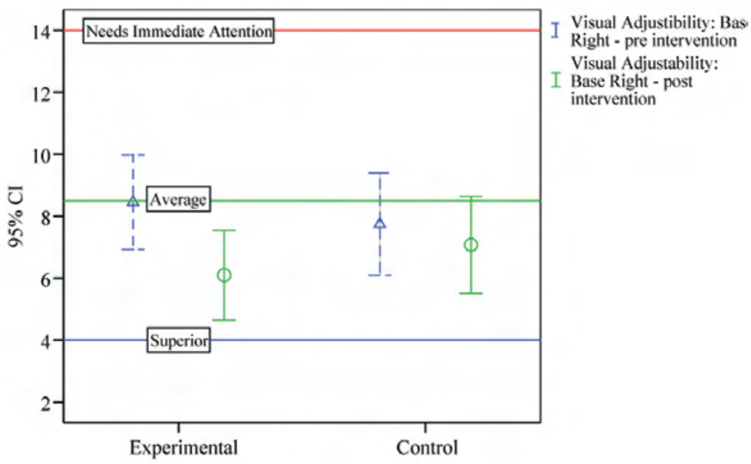


Figure 12: Visual Adjustability - Base Right



Firstly, a comparison was made between experimental and control groups, for post-intervention measurements. For the visual skills fusion flexibility (distance and near) and visualization, the mean values are similar for the experimental and control groups. For central-peripheral awareness, eye-hand/eye-body coordination, visual response time (right and left) and visual adjustability (in all four directions of the prism's base) differences are found between the mean values of the experimental and control groups. These skills - that do show a difference in the post-intervention measurements between the experimental and control groups - fall under the category of software skills. The graphs clearly indicate a tendency towards better results in these software skills, after doing the intervention programme but show not to be statistically significant ($p<0.05$).

Secondly, the difference in values between the pre- and post intervention measurements for each of the software skills, for the experimental and control groups, was investigated separately (figures 1-12). For the experimental group, differences in pre/post intervention measurements were found for the visual skills central-peripheral awareness, eye-hand and eye-body coordination, visual response time (right and left hands), visual adjustability (prism base facing to the right) and visualization. These differences were however, not statistically significant. For the control group, no statistical significant differences in pre/post intervention measurements were found for the visual skills central-peripheral awareness, eye-hand and eye-body coordination, visual response time (right and left hands), and visualization.

Thirdly, a comparison of the results of the pre- and post-intervention measurements for the software skills and fusion flexibility, was made to the norms determined by Buys[3]. The Mann-Whitney U test showed no statistical differences between the results of the experimental and control groups for any of the following skills, when comparing the pre-intervention measures of the two groups. After the five week intervention programme, the data revealed that there were still no statistical significant differences between the results of the experimental and control groups, for fusion flexibility (distance and near) or visualization. No improvement in these skills were found for the experimental groups after participating in the programme. After completion of the intervention program the results showed a superiority in the experimental group for central-peripheral awareness, eye-hand coordination, eye-body coordination, visual response time (right and left hands respectively) and visual adjustability (with the prism based in all four directions respectively). This improvement in the results of the experimental group was not statistically significant.

Fourthly, a comparison was made between the results of the lower levels (levels 1-5) and higher level gymnasts (levels 6-12), for the experimental and control groups respectively. These results are aimed to compare the pre- and post-intervention measures of each group (experimental and control) between the different levels of rhythmic gymnastics participation, rather than comparing the two groups or the two sets of measurements with each other. On first glance, it seems that there is no statistically significant difference between pre- and post-intervention results, for most of the visual skills. However, when taking a closer look it is clear that the large range of levels of participation has a big influence on the results. When the levels are split into lower and higher levels of participation, the effect of the intervention programme on the different levels can be seen more clearly. Also, the effect of this programme on the experimental group (versus the control group) is shown in graphs 13-26 below.

Figure 13: Fusion Flexibility: near - pre intervention

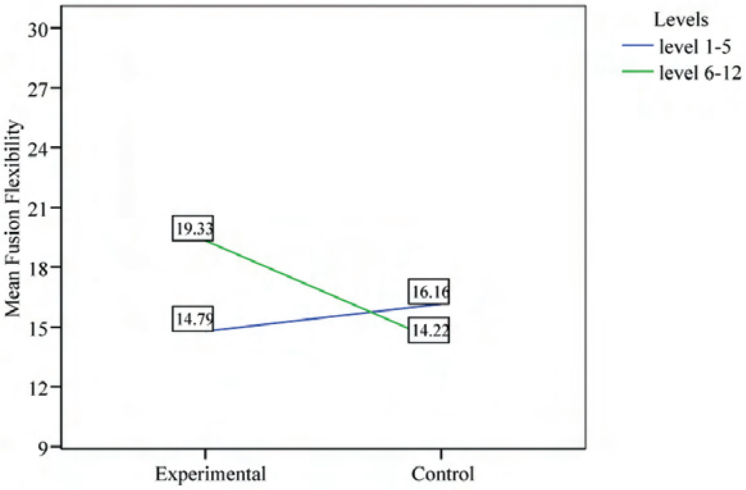


Figure 14: Fusion Flexibility: near - post intervention

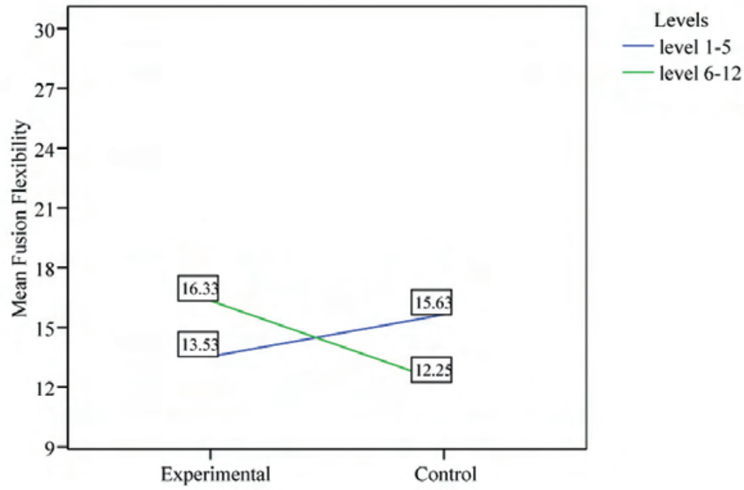


Figure 15: Fusion Flexibility: distance - pre intervention

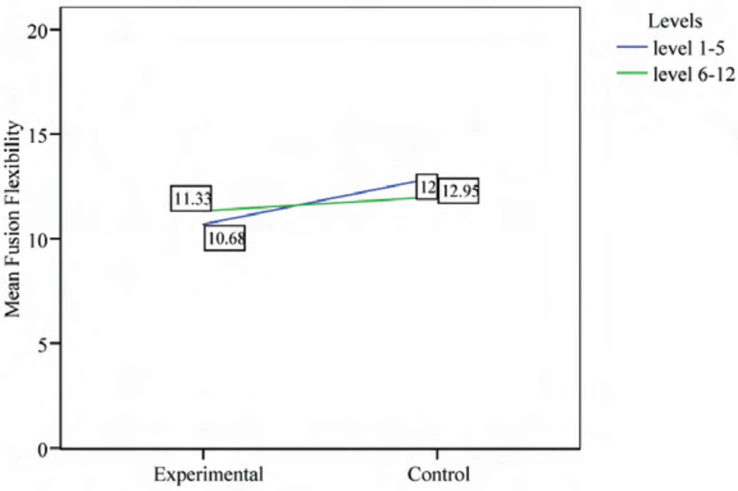


Figure 16: Fusion Flexibility: Distance - post intervention

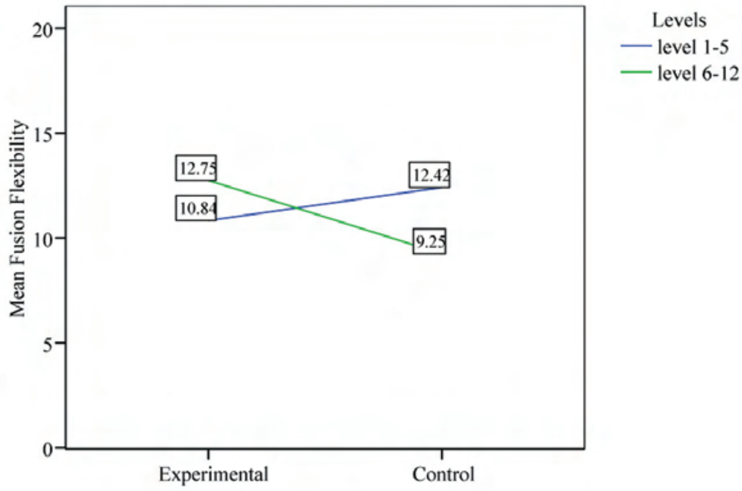


Figure 17: Central - Peripheral Awareness - pre intervention

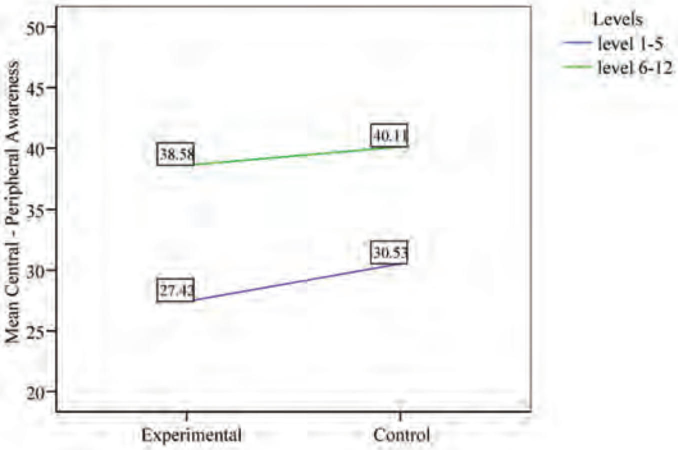


Figure 18: Central - Peripheral Awareness - post intervention

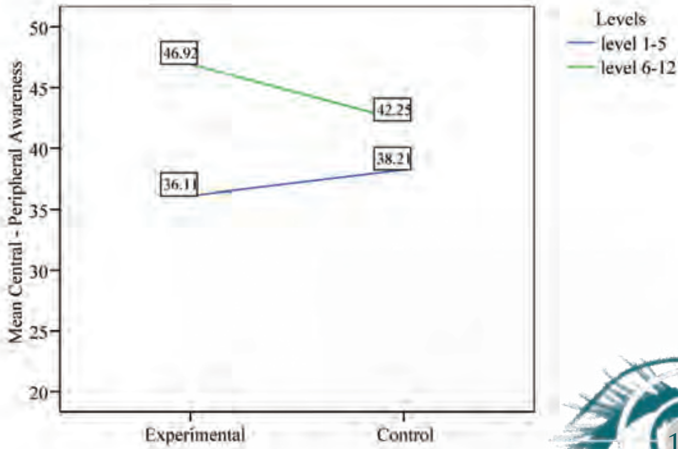


Figure 19: Visualization (Getman) - pre intervention

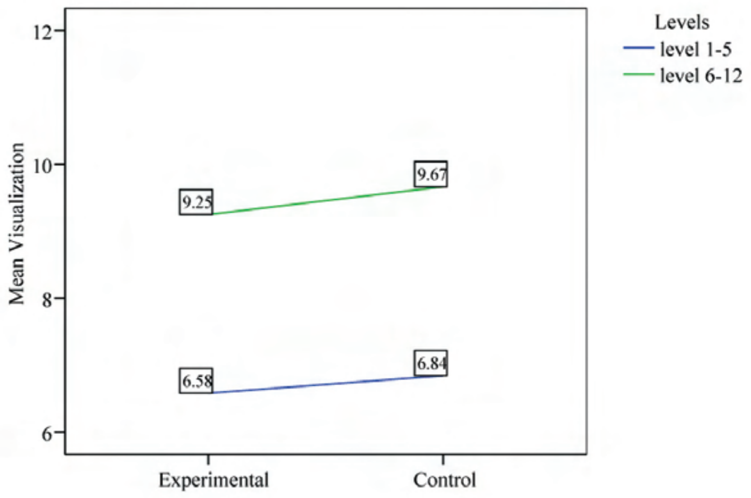


Figure 20: Visualization (Getman) - post intervention

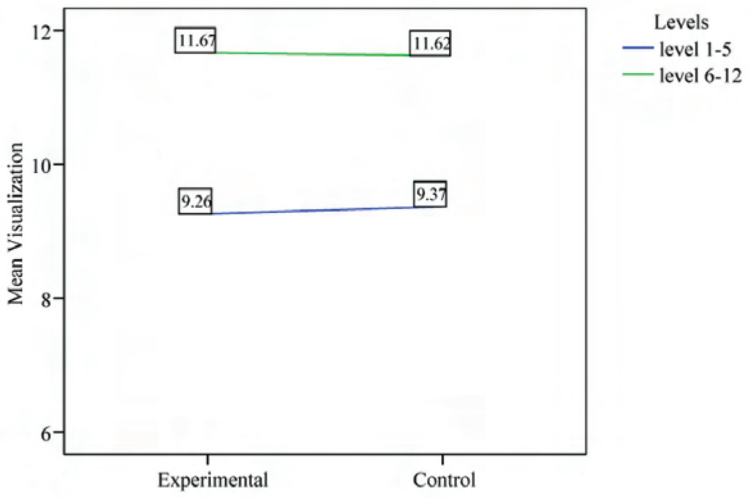


Figure 21: Eye-hand Coordination - pre intervention

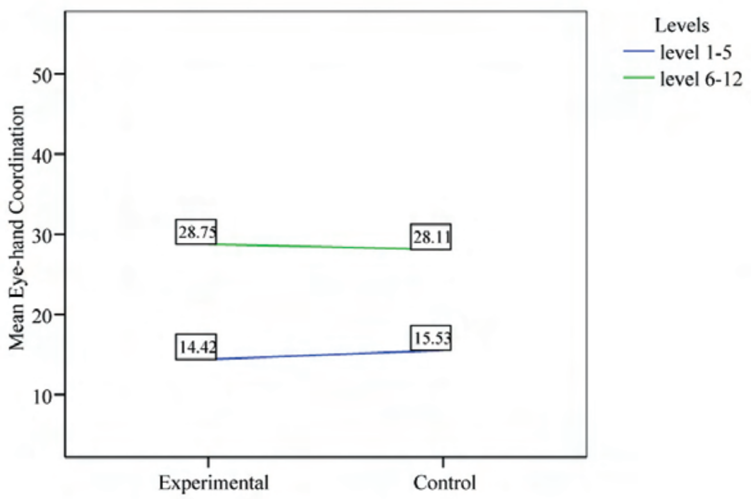


Figure 22: Eye-hand Coordination - post intervention

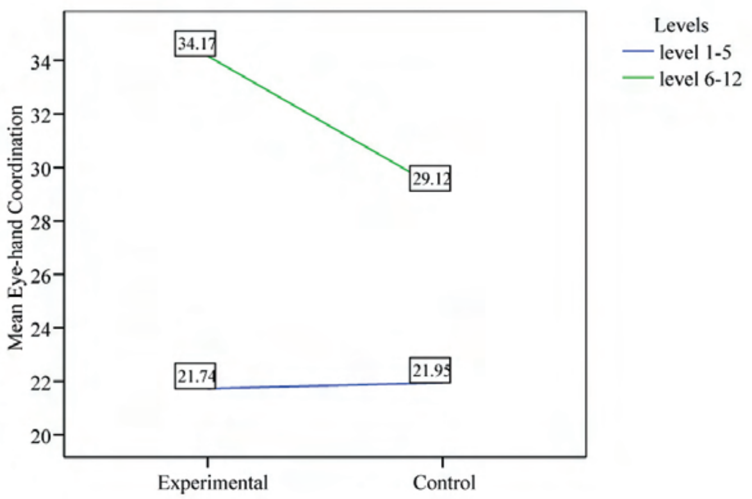


Figure 23: Eye-body Coordination - pre intervention

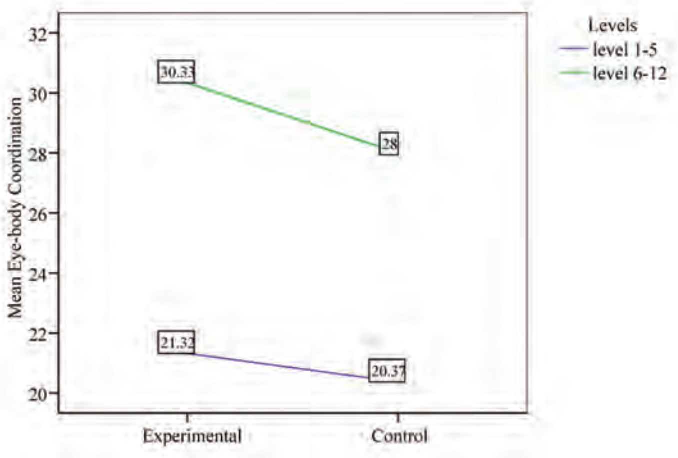


Figure 24: Eye-body Coordination - post intervention

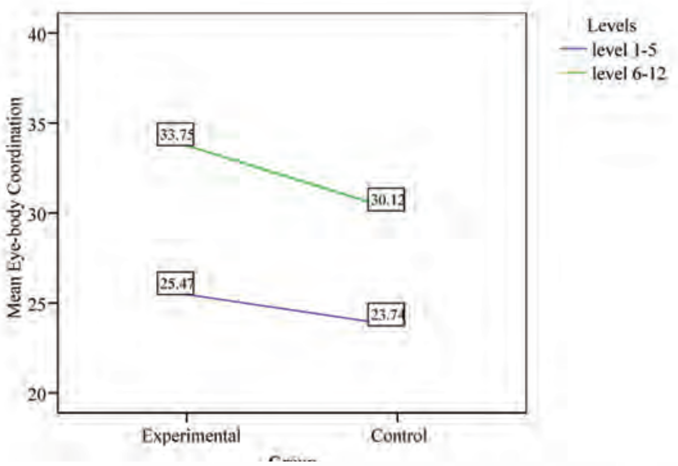


Figure 25: Visual Reaction Time: Right - pre intervention

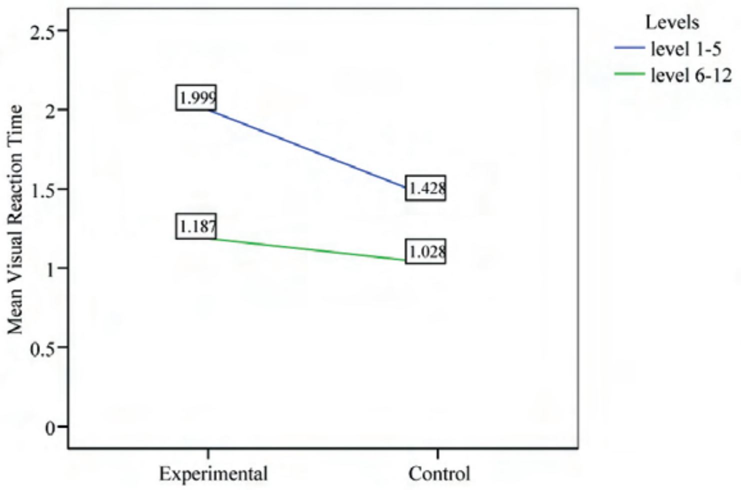


Figure 26: Visual Reaction Time: Right - post intervention

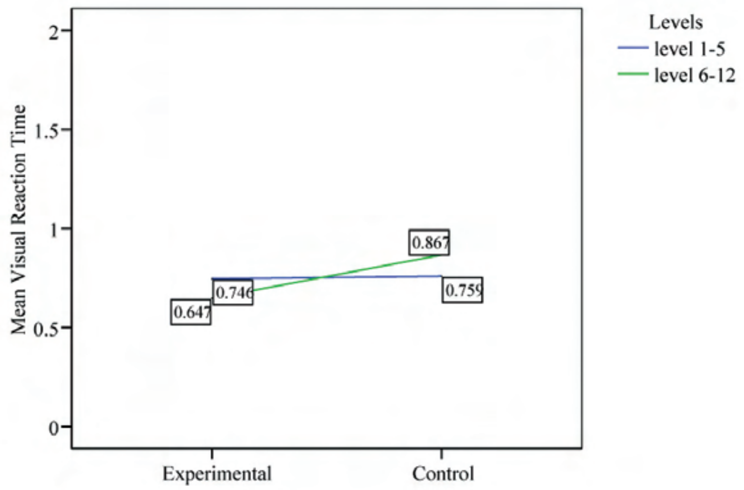


Figure 27: Visual Reaction Time: Left - pre intervention

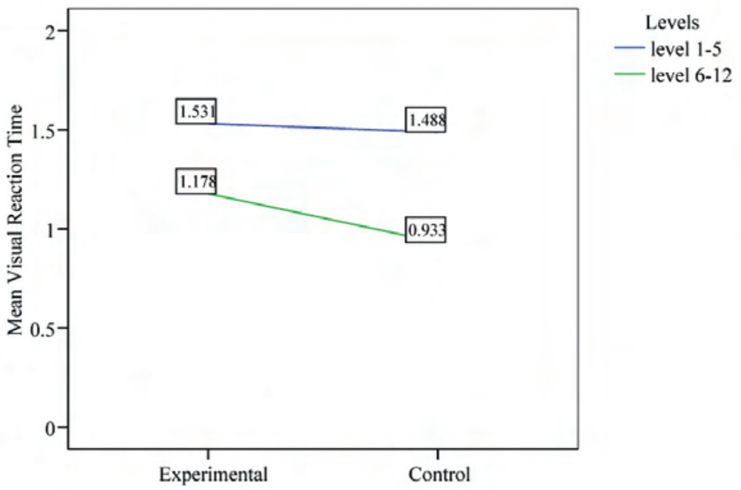


Figure 28: Visual Reaction Time: Left - post intervention

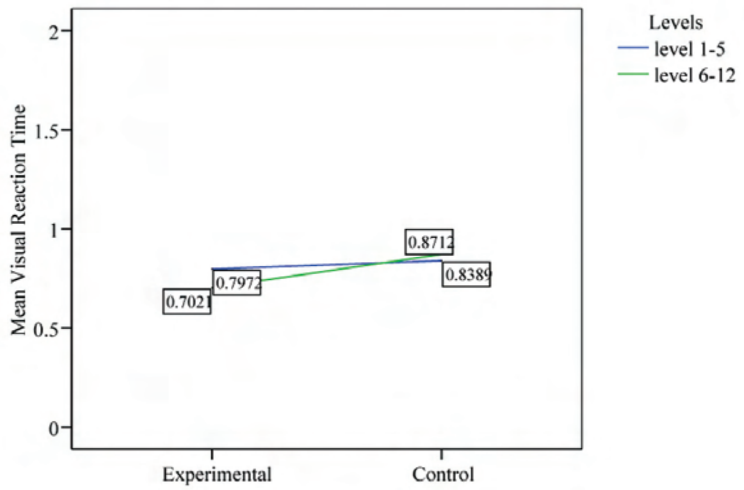


Figure 29: Visual Adjustibility: Base Up - pre intervention

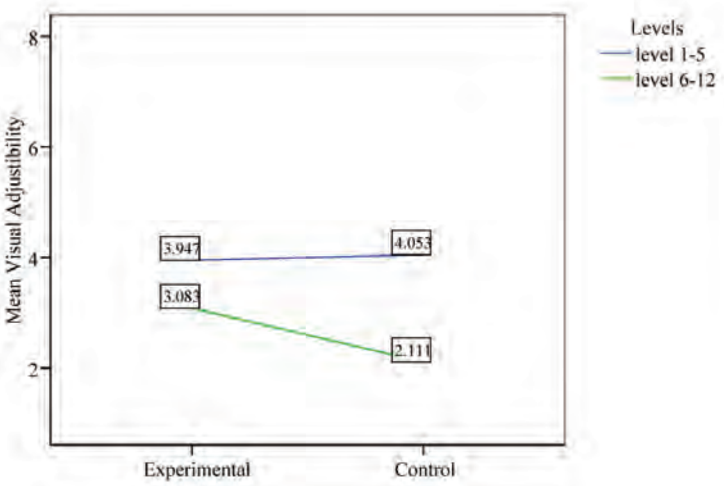


Figure 30: Visual Adjustibility: Base Up - post intervention

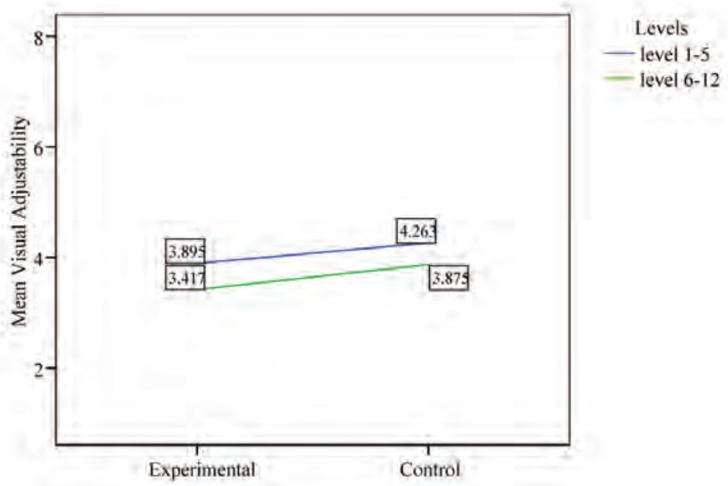


Figure 31: Visual Adjustibility: Base Down - pre intervention

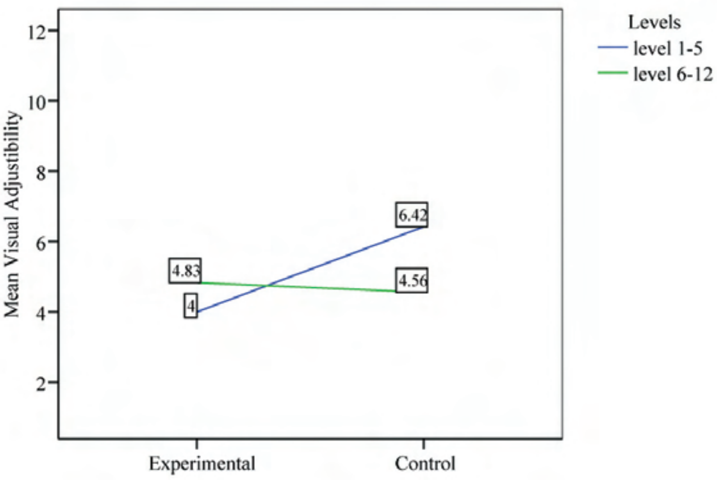


Figure 32: Visual Adjustibility: Base Down - post intervention

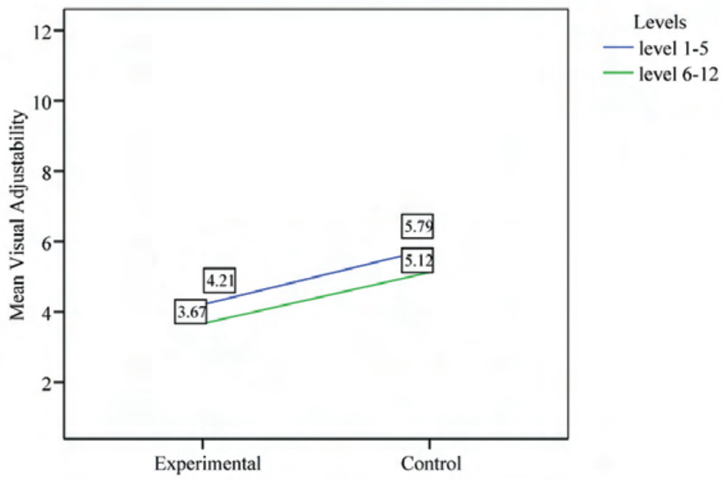


Figure 33: Visual Adjustibility: Base Left - pre intervention

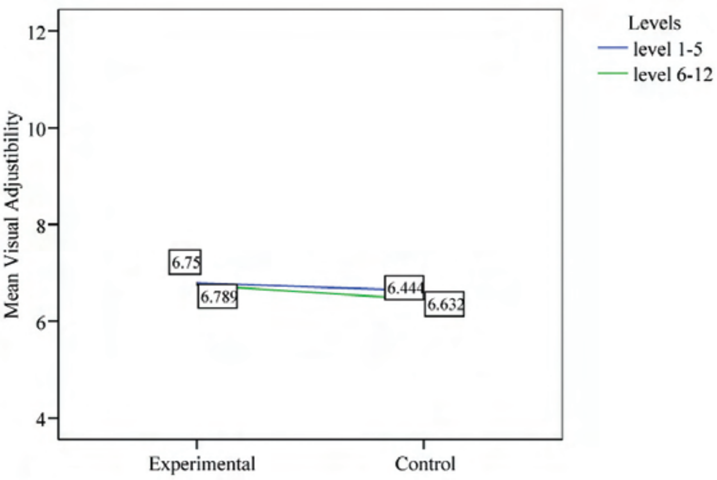


Figure 34: Visual Adjustibility: Base Left - post intervention

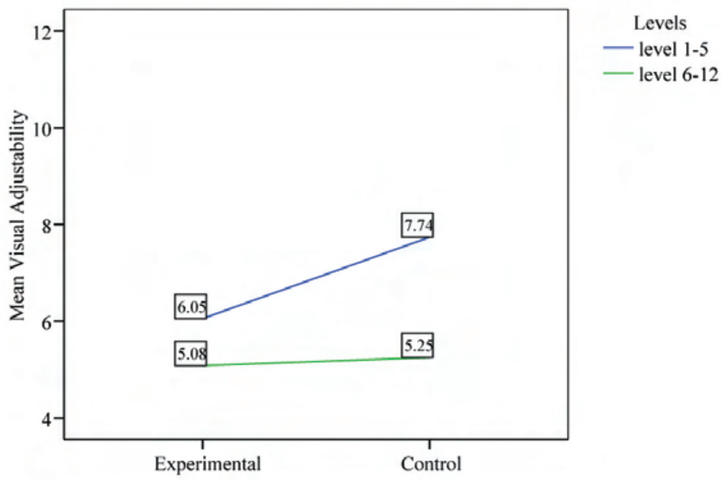


Figure 35: Visual Adjustibility: Base Right - pre intervention

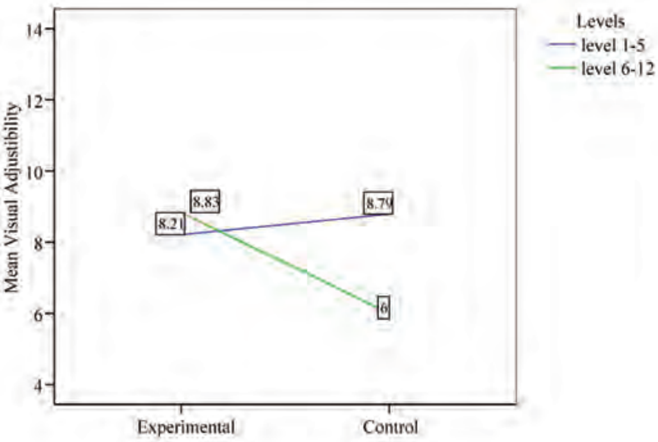
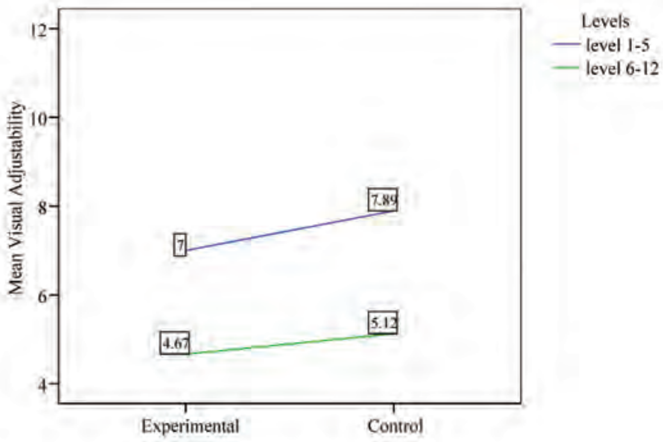


Figure 36: Visual Adjustibility: Base Right - post intervention



When comparing the results for fusion flexibility (near), for the higher and lower levels, neither the experimental nor the control groups showed any improvement. A bigger difference between pre- and post-intervention measures was found in the higher levels, and more so for the experimental than the control group. For fusion flexibility (distance) the higher levels showed an improvement from pre- to post-intervention measurements for the experimental group. The results of the lower levels stayed more or less the same. It is important to keep in mind that the initial measurements of visual skills (pre-intervention) for the experimental and control groups, of the lower and higher levels, were statistically comparable. The results found for the lower levels as indicated above masked the results which showed improved performance by the higher levels.

Start-off values for central-peripheral awareness, eye-hand coordination, eye-body coordination and visual response time (right hand) for the experimental and control groups, for all levels were statistically comparable. The lower levels show lower starting values (pre-intervention measures) for both experimental and control groups than the higher levels. They further show lower end values (post-intervention measures) for both of these groups. These lower levels influenced (and lowered) the mean values of both the experimental and control groups, and also of the total sample group. The general improvement in performance of the total group of levels who participated in the study (when looking at post-intervention measurements) is therefore masked by the poor performance of the lower levels. Though both groups of levels showed improvement in post-intervention results for the left hand, the performance of the higher levels are not seen very clearly due to the lesser extend of improvement by the lower level gymnasts. If the two groups of levels were split throughout the study the improvement due to the intervention programme might have been much more evident. The larger amount of improvement found for the higher levels, does however indicate a positive argument on behalf of the intervention programme.

Visual adjustability shows the following results: For base-up measures, the only group who showed improved results after participating in the intervention programme, is the experimental group of the lower levels. This improvement is however so small that it is not statistically significant. One can therefore conclude that for visual adjustability with the prisms facing base-up, no real improvement was found in any group present. An improvement in the experimental group's results was also found for base-down measurements. The experimental group of the higher levels showed improvement that is masked by the poorer performance of the lower levels, when taking into account the results of the total group of gymnasts. The reliability of the test is questioned. The figures used to present the results are a much better indication of the true results than the numerical values, when comparing pre- and post-intervention measurements to each other. These figures are available on request. Better performance by the experimental group of the higher levels, as compared to results of the control group, is seen graphically for base-left measurements. Also, the performance of the lower levels is demonstrated. From the figures it can be seen how the performance of these lower levels masks the improvement found by the higher levels. Base-left measures showed an improvement in performance for both groups when tested after completion of the programme. The biggest improvement was for the experimental group.

Discussion

The discussion can be divided into the two sections. Section A explains the data found for the hardware measurements as well as the comparison thereof to the norms determined by Buys[30] in 2002. In Section B the results of the software skills are discussed for pre- and post measurements, and are compared between the experimental and control groups. The comparison between the levels of gymnasts and the norms of the skills as determined by Buys[30] are also discussed.

Section A:

Coffee & Reichow[17, 33] made use of mean and standard deviation values when analyzing their results, which can be compared to Ferreira (2002)[34], Langhout (2007)[31], Nel (2006)[32] and Van Zyl (2006)[12] who suggests that the hardware skills of the visual system do not differ between athletes and the normal population. The gymnasts' results for the hardware skills were mostly lower than that found by Langhout[31] for the older population. Their results were found to be slightly better than the young athletes of

Nel[32] and comparable to that of van Zyl's[12] athletes. To conclude, no major differences were found by previous researchers with regard to hardware skills. One must therefore be careful not to make the mistake of emphasizing training of the hardware system when it comes to intervention programmes and sport specific visual training.[34] For this reason, the hardware skills were tested only once with the purpose of reporting the results of these skills, for rhythmic gymnasts. No intervention programme was followed for the hardware skills, except for fusion flexibility.

The measurements for fusion flexibility of the experimental and control groups were statistically comparable. After completion of the intervention programme no improvement was seen for the experimental group. Although eye muscles allow for motor elements in fusion flexibility, this skill does not show motor element with regard to trainability.

Section B:

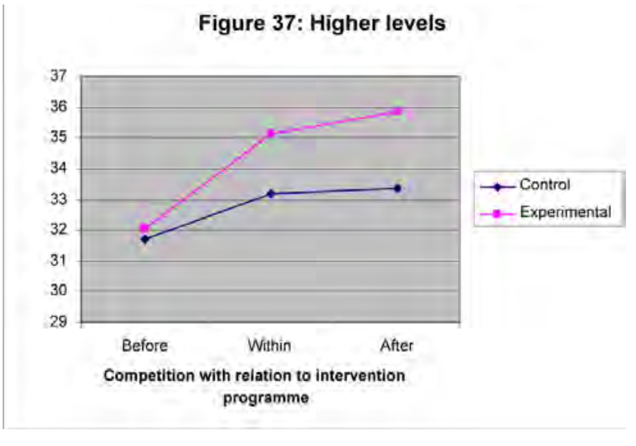
When analyzing the pre-intervention measurements of the software skills the following was found: For each skill, the measurements of the experimental and control groups were statistically comparable. Therefore, the post-interventional measurements between the experimental and control groups could be compared. The experimental group shared a general tendency towards an improvement in the software skills after doing the intervention programme for only five weeks. It is expected that a larger training period might result in statistically significant improvement in the values of the results. For the control group, a slight improvement can be seen in the software skills after the gymnasts continued with their normal training routine for five weeks. Familiarity with testing procedures may be the biggest reason for this observation.

The post-intervenional measurements could be compared between the experimental and control groups for the lower levels (levels 1-5) and the higher levels (levels 6-12) of rhythmic gymnastics participation. Post-interventional results for the experimental group of the higher levels were often found to be better than the results of the control group. The control groups of both sets of levels sometimes showed improvements post-interventional. This raises a question over the effectiveness of the intervention programme. However, as the experimental groups mostly show more improvement than the control groups, it is likely that this improvement is due to more than just the placebo effect and familiarity with the testing methods and apparatus used. The argument in favour of the intervention programme is further supported by studying the results of the different levels. When the levels are split into lower and higher levels, it is clear that the experimental group of the higher levels showed improvement in their post-intervention results. This improvement is masked by the performance of the experimental group of the lower levels. An intervention programme therefore has to be made age appropriate for the lower levels to investigate its true effect.

The software visual skills - central-peripheral awareness, eye-hand/eye-body coordination, visual response time (right and left) and visual adjustability (in all four directions of the prism's base) - show motor elements and therefore an improvement in results of the experimental group is found with these skills after training. For visualization, however, no improvement was found for the experimental group post-interventionally. This opens the question of whether visualization is a software skill, or rather a hardware skill with relation to trainability.

Results from three different competitions were gained for the higher level gymnasts to investigate whether the improved skills lead to improved perfromance. The occurrence of these competitions was spread throughout the study to coincide with the timing of the intervention programme. The first competition took place before the intervention programme was introduced to the experimental group of gymnasts. The second was held during the course of the intervention programme. The gymnasts participated in the third competition after the intervention programme was completed and the visual skills trained were retested on both the experimental and control groups.

For the competition that took place before the start of the intervention programme, only a small difference was found between the results of the experimental group and that of the control group. For the second competition, which was held during the time in which the programme was followed by the experimental group, better results were found for this group than for the control group of gymnasts. The third competition, which took place after the intervention programme was completed, revealed much better results for the experimental group than for the control group. The experimental group therefore showed improved competition results on each new set of results. This improvement in competition results for the experimental group of the higher levels are seen here much better than in the previous section, which dealt with lower versus higher levels of rhythmic gymnastics participation. As the results for the lower and higher levels are split and therefore not interfering with each other, the improved performance of the experimental group of the higher levels after completion of the intervention programme can be seen. Even better results would be expected from an intervention programme with a duration longer than five weeks. Figure 37 illustrates the results found for the competitions.



Implications of the study

The implications of the present study on the sport of rhythmic gymnastics could be the following: First, as the effect of a visual intervention programme seems to be positive, such a programme could be made part of the rhythmic gymnasts' general training routine. This ongoing visual skill training would be expected to not only improve the gymnasts' software visual skills, but to also prevent these skills from regressing and eventually going back to their original state as was found before the implementation of this intervention programme. Second, as the improved visual skills were found to have a positive effect on the competition results of the higher level gymnasts, a visual intervention programme may be a key factor in improving the competition performance of the South African rhythmic gymnasts, which would increase their chances against gymnasts from other countries when it comes to international competitions. The intervention programme would, however, have to be made sport specific, age specific and level specific.

Conclusion

It can be concluded that firstly the important visual skills in rhythmic gymnastics are the software skills, namely eye-hand and eye-body coordination, central-peripheral awareness, visual response time, visual adjustability and visualization. Fusion flexibility, as being a hardware skill, may not be as important in this specific sport unless major deficiencies are present. Secondly, this specific sample of individuals, the findings suggest that the implementation of an intervention programme may lead to improved visual skills. Improved performance due to the intervention programme is seen more in higher level rhythmic gymnasts than in those participating in the lower levels. The changes in results of the higher levels from pre- to postintervention measurements, are masked by the performance of the lower levels. The effect of the intervention programme could therefore not be seen to its full potential.

The intervention programme must be followed on a long-term or even permanent basis to ensure an ongoing improvement with the possibility of the transfer of this improvement to performance during competition. Improved performance after the implementation of an intervention programme might be seen in the practical sporting situation, although the statistical analysis of post-training results may not show significant changes from pre-training measurements.

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