Effects of Balance Training Combined with Visual Tasks on Balance Ability and Myopia Progression in Children: A 12-week School-based Intervention

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Abstract

Objective: To investigate the effects of integrating balance training and visual tasks into physical education (PE) curriculum on improving balance ability and delaying myopia progression in children. Methods: A total of 62 children aged 9-11 years old were assigned into two groups: an intervention group (balance training integrated into regular PE classes with additional visual tasks, n=31) and a control group (regular PE classes only, n=31). The 12-week intervention was conducted at a frequency of three times per week. Pre-test and post-test intervention assessments included visual acuity (uncorrected distance visual acuity, change in spherical equivalent) as well as static and dynamic balance ability. Changes in outcome measures were analyzed. Results: In terms of visual outcomes, the intervention group with myopia showed a significant improvement in uncorrected distance visual acuity (p=0.014), and the change in spherical equivalent was significantly better than that of the control group (p=0.049), suggesting that the intervention incorporating visual tasks may help slow myopia progression. Regarding balance ability, the improvement in dynamic balance was significantly greater in the intervention group than in the control group (p<0.001). Static balance improved in both groups, with no significant between-group differences. Conclusion: Integrating balance training into regular PE classes effectively improves both static and dynamic balance in children. Adding visual tasks to balance training can delay myopia progression to a certain extent while enhancing balance ability.

Keywords

Children, Balance ability, Balance training, Visual training, Myopia progression

Introduction

Myopia has become a major public health issue affecting the visual health of children and adolescents. In the coming decades, the proportion of people affected by myopia will inevitably rise. According to current trends, it is projected that by 2050, the global prevalence of myopia will affect approximately 5 billion people, with about 740 million children and adolescents affected [1]. In China, the prevalence of myopia among children and adolescents is expected to reach 61.3% [2].

Human balance is maintained through the acquisition of peripheral sensory information, which is then integrated by the central nervous system to control motor effectors and produce appropriate postural reflexes. The visual system is one of the three major sensory systems (vestibular, visual, and proprioceptive) involved in this process [3,4]. Studies on the effects of the visual system on balance have shown that increased refractive blur leads to reduced postural stability and balance ability [5]. Among children aged 9-11 years, myopic children have been found to exhibit weaker dynamic balance compared to non-myopic peers [6]. Myopia impairs postural control and disrupts balance maintenance, thereby increasing the risk of falling and injury [7]. Regular physical activity can effectively improve individual balance ability. For myopic children, physical activity can partially substitute for ocular function training, enhancing the accuracy and coordination of ciliary muscle accommodation, promoting changes in ocular parameters, and supporting visual health [8]. By incorporating extra visual tasks into physical activity, eye movements are strengthened, and appropriate additional demands are placed on the visual system, leading to improvements in dynamic visual acuity, uncorrected visual acuity, and balance ability [9,10].

Objects and methods

Participants

From March to June 2025, two fourth-grade classes from a primary school in Panjin City were selected as participants. One class served as the intervention group and the other as the control group. Inclusion criteria were age 9-11 years old, good physical health and normal development, and ability to participate in regular physical exercise. For myopic participants, additional criteria included: binocular uncorrected visual acuity <5.0, spherical equivalent (SE) ≤-0.5D (based on the more myopic eye), no history of orthokeratology lens wear, no pathological ocular diseases, and good functional status apart from myopia. A total of 62 children were enrolled, including 31 in the intervention group (19 myopic, 12 non-myopic) and 31 in the control group (17 myopic, 14 non-myopic). No significant between-group difference was found in myopia rate (p=0.373). Baseline comparisons of uncorrected visual acuity, static balance, and dynamic balance between children with the same visual status in the two groups showed no significant differences (p>0.05).

Methods

(1) Intervention design

The intervention was conducted at the children's school for over 12 weeks. The intervention group received balance training and visual tasks integrated into three 45-minute PE classes per week, while the control group continued with three 45-minute regular PE classes per week. The balance training protocol was adjusted over the 12 weeks based on participants' performance, including six exercises performed twice per week. As training progressed, static and dynamic balance exercises were modified. This was achieved by reducing the base of support, increasing the oscillation of the center of gravity over the base of support, eliminating visual feedback (eyes closed), and changing the surface types for standing and performing exercises. For ciliary muscle (near-far) accommodation training delivered through physical activity, 30 near-far visual identification tasks per session have been shown to have the most significant effect on improving dynamic vision and uncorrected distance visual acuity in children. A 3-second visual target presentation duration was identified as optimal for improving visual acuity in primary school children. Based on these findings, the intervention protocol adopted 30 near-far visual identification tasks with a 3-second presentation duration, integrating near-far visual target accommodation training into the class content appropriately and effectively [11]. All instructions were delivered by the author.

(2) Outcome measures

All tests were conducted once before and after the intervention. Measurements included height, weight, static balance ability (eyes-open single-leg stance, eyes-closed single-leg stance), dynamic balance ability (Y-Balance Test, YBT), uncorrected distance visual acuity (recording the worse eye), and spherical equivalent (SE). Change in SE was calculated as an indicator of myopia progression using the formula: ΔSE=(left eye SE change)+(right eye SE change). The effects of different interventions on children's visual acuity and balance ability were compared.

Statistical analysis

Statistical analyses were performed using SPSS 27.0. For within-group comparisons before and after the intervention, data following a normal distribution were analyzed using paired-sample t-tests, while non-normally distributed data were analyzed using the Wilcoxon signed-rank test. For between-group comparisons of intervention effects, the pre-post difference (post-test minus pre-test) was calculated for each participant. Between-group differences in these change scores were analyzed using independent-sample t-tests for normally distributed data and the Mann-Whitney U test for non-normally distributed data. Statistical significance was set at p<0.05.

Results

Changes in visual acuity and balance ability in the intervention group by visual status

As shown in Table 1, the intervention group with myopia showed a statistically significant improvement in uncorrected distance visual acuity (p<0.05). Regarding static balance, eyes-open single-leg stance time was significantly prolonged after the intervention (p<0.001), while eyes-closed single-leg stance time showed a slight improvement that did not reach statistical significance (p=0.277). In dynamic balance, Y-Balance Test (YBT) anterior, posterolateral, and posteromedial distances all increased significantly from baseline, with particularly notable improvements in anterior and posteromedial distances. The composite score also showed a highly significant improvement. All dynamic balance measures reached statistical significance (p<0.001), indicating that the intervention had a statistically significant effect on improving dynamic balance in myopic children.

Table 1. Pre- test and post-test intervention comparisons of outcome measures in the intervention group with myopia.

Measure	Pre-test	Post-test	t/Z	p
Uncorrected distance visual acuity	4.56±0.26	4.63±0.22	2.727	0.014*
Eyes-open single-leg stance (s)	21.99±8.34	35.46±13.59	3.582▲	<0.001***
Eyes-closed single-leg stance (s)	12.78±5.97	14.94±10.59	1.087▲	0.277
YBT anterior (cm)	59.37±3.50	74.67±5.65	10.818	<0.001***
YBT posterolateral (cm)	59.79±7.09	70.75±5.59	7.620	<0.001***
YBT posteromedial (cm)	63.32±5.36	79.75±7.28	11.081	<0.001***
YBT composite score (%)	82.22±6.16	101.53±9.30	14.904	<0.001***

Note: “▲” indicates non-normally distributed data; the values shown are t/Z -values from the Wilcoxon signed-rank test. *p<0.05, **p<0.01, ***p<0.001. The same applies to the following tables.

As shown in Table 2, in the intervention group without myopia, uncorrected distance visual acuity showed a slight improvement that did not reach statistical significance (p=0.157). Regarding static balance, eyes-open single-leg stance time was significantly prolonged (p<0.05), while eyes-closed single-leg stance time showed an increase that did not reach statistical significance (p=0.161). In dynamic balance, YBT anterior, posterolateral, posteromedial reach distances, and the composite score all increased significantly from baseline, reaching clear statistical significance (p<0.01). This indicates that the training protocol integrating balance training with additional visual tasks into regular PE classes exerted a statistically significant positive effect on improving dynamic balance in non-myopic children.

Table 2. Pre-test and post-test intervention comparisons of outcome measures in the intervention group without myopia.

Measure	Pre-test	Post-test	t/Z	p
Uncorrected distance visual acuity	4.98±0.05	4.99±0.03	1.414▲	0.157
Eyes-open single-leg stance (s)	34.09±9.54	40.18±10.22	2.090▲	0.037*
Eyes-closed single-leg stance (s)	11.79±4.61	16.05±11.39	1.501	0.161
YBT anterior (cm)	61.94±3.40	76.42±7.63	6.581	<0.001***
YBT posterolateral (cm)	60.83±7.24	71.64±6.42	3.061▲	0.002**
YBT posteromedial (cm)	69.08±5.63	81.86±6.94	8.693	<0.001***
YBT composite score (%)	86.31±7.10	103.55±10.80	9.120	<0.001***

Changes in visual acuity and balance ability in the control group by visual status

As shown in Table 3, in the myopia control group, no significant improvement was found in uncorrected distance visual acuity (p=0.923). Regarding static balance, eyes-open single-leg stance time was significantly prolonged (p=0.003), while eyes-closed single-leg stance time showed a slight improvement without statistical significance (p=0.103). In dynamic balance, anterior distance increased significantly from baseline (p=0.011), but changes in posterolateral and posteromedial distances did not reach significance (p>0.05). The YBT composite score improved but also did not reach statistical significance (p=0.067).

Table 3. Pre-test and post-test intervention comparisons of outcome measures in the control group with myopia.

Measure	Pre-test	Post-test	t/Z	p
Uncorrected distance visual acuity	4.54±0.28	4.49±0.30	0.099	0.923
Eyes-open single-leg stance (s)	23.37±4.93	32.68±9.85	3.488	0.003**
Eyes-closed single-leg stance (s)	10.68±4.16	14.78±9.72	1.349▲	0.177

Measure	Pre-test	Post-test	t/Z	p
YBT anterior (cm)	59.41±5.29	62.00±5.17	2.866	0.011*
YBT posterolateral (cm)	57.65±8.13	57.98±8.30	0.334	0.743
YBT posteromedial (cm)	63.69±7.70	65.57±6.96	1.499	0.167
YBT composite score (%)	82.46±11.81	84.66±11.66	1.966	0.067

As shown in Table 4, in the control group without myopia, no statistically significant improvement was observed in uncorrected distance visual acuity (p=0.739), and none of the functional outcome measures showed significant changes. In static balance, changes in eyes-open (p=0.894) and eyes-closed (p=0.331) single-leg stance times were not statistically significant. In dynamic balance, changes in YBT anterior, posterolateral, posteromedial distances, and the composite score all failed to reach significance (p>0.05).

Table 4. Pre-test and post-test intervention comparisons of outcome measures in the control group without myopia.

Measure	Pre-test	Post-test	t/Z	p
Uncorrected distance visual acuity	4.92±0.12	4.92±0.12	0.333▲	0.739
Eyes-open single-leg stance (s)	34.22±5.71	34.61±12.52	0.136	0.894
Eyes-closed single-leg stance (s)	14.55±3.75	13.88±9.01	0.973▲	0.331
YBT anterior (cm)	65.21±5.07	63.79±6.85	1.193	0.254
YBT posterolateral (cm)	60.69±8.29	59.71±9.82	0.589	0.566
YBT posteromedial (cm)	66.57±7.50	69.07±8.78	1.086	0.297
YBT composite score (%)	87.56±7.36	90.86±14.09	0.879	0.395

Comparison of intervention effects on visual acuity and balance ability between groups

To compare the effects of different interventions on myopia progression, the change in spherical equivalent (ΔSE) was calculated for each participant. For children diagnosed with myopia at baseline (SE ≤-0.50 D), a negative ΔSE indicates myopia progression (worsening of refractive status), a positive ΔSE indicates no progression or regression (improvement), and zero indicates no change. For children without myopia at baseline (SE >-0.50 D), a positive ΔSE indicates a shift toward myopia (worsening, i.e., depletion of hyperopic reserve or development of myopia), a negative ΔSE indicates a shift toward hyperopia (non-worsening), and zero indicates no shift. Among myopic children, the intervention group showed statistically significant differences compared to the control group in uncorrected distance visual acuity and ΔSE (p<0.05). In static balance, no statistically significant differences were observed between the two groups. However, the intervention group demonstrated significantly better performance in all three YBT directions (anterior, posterolateral, posteromedial) and the composite score compared to the control group (p<0.01).

Table 5. Comparison of changes in outcome measures between intervention and control groups (myopic children).

Measure	Intervention group	Control group	t	p
Uncorrected distance visual acuity	0.07±0.08	-0.05±0.16	2.644#	0.043*
ΔSE (D)	-0.32±0.18	-0.58±0.39	2.588#	0.049*
Eyes-open single-leg stance (s)	13.46±11.18	9.31±11.00	1.189	0.240
Eyes-closed single-leg stance (s)	2.16±6.75	4.10±9.80	0.648	0.520
YBT anterior (cm)	15.30±6.16	2.59±3.72	7.575#	<0.001***
YBT posterolateral (cm)	10.96±6.27	0.33±4.11	6.072#	<0.001***
YBT posteromedial (cm)	16.44±6.47	1.88±5.36	7.382#	<0.001***
YBT composite score (%)	19.31±5.65	2.21±4.63	9.978#	<0.001***

Note: "#" indicates normally distributed data with unequal variances; the t-values shown are Tamhane's T2 results. The same applies to the following tables.

Among non-myopic children, no statistically significant differences were found between the two groups in visual acuity or ΔSE ($p>0.05$). Regarding static balance, no significant intervention effect was observed, suggesting that postural control ability was similar between groups after the intervention period. In dynamic balance, the intervention group showed significantly greater improvements than the control group in YBT anterior and posterolateral distances as well as the composite score ($p<0.05$).

Table 6. Comparison of changes in outcome measures between intervention and control groups (non-myopic children).

Measure	Intervention group	Control group	t/Z	p
Uncorrected distance visual acuity	0.02±0.04	0.00±0.10	0.000^	1.000
ΔSE (D)	0.44±0.22	0.53±0.44	0.675#	0.881
Eyes-open single-leg stance (s)	6.09±8.89	0.39±10.82	1.544	0.130
Eyes-closed single-leg stance (s)	4.26±9.82	-0.67±7.14	1.594^	0.111
YBT anterior (cm)	14.47±7.62	-1.43±4.48	6.351#	<0.001***
YBT posterolateral (cm)	10.81±6.09	-0.98±6.20	4.599	<0.001***
YBT posteromedial (cm)	12.78±5.09	2.50±8.61	3.778	<0.001***
YBT composite score (%)	17.24±6.55	3.30±14.06	3.600^	<0.001***

Note: “^” indicates non-normal distribution, and the values in the table are t/Z-values obtained from the Mann-Whitney U test.

Discussion

The observed effects on visual acuity in myopic children suggest that the intervention may help slow myopia progression. This finding is consistent with many previous research studies showing that incorporating ciliary muscle accommodation training into physical activity can effectively improve dynamic vision and uncorrected visual acuity in children. The added visual task training included systematic near-far alternating tasks, which have been shown to effectively promote rhythmic contraction and relaxation of the ciliary muscle, thereby significantly enhancing accommodative amplitude and accuracy. This may help alleviate accommodative spasm and visual fatigue caused by prolonged near-work, subsequently improving dynamic vision and accommodative function [12,13].

The inclusion of visual tasks introduces a cognitive-motor coordination challenge, strengthening the central nervous system’s capacity for integrating proximal trunk stabilizer muscles with visual-vestibular information. For myopic children who rely on visual compensation, such training may partially compensate for the reduced reliance on proprioceptive feedback from trunk movement caused by blurred vision, leading to better performance in this composite task [14]. Furthermore, as a dual-task paradigm, this “cognitive-motor” dual-task condition imposes higher demands on central executive function. Research indicates that the parietal cortex plays a core and differentiated role in sensorimotor integration and balance control [15]. Through training, the brain’s resource allocation strategy between visual information processing and postural control may be optimized, indirectly enhancing the efficiency and stability of visual processing while improving balance task performance.

Conclusion

Integrating balance training with additional visual tasks into regular PE classes significantly improves uncorrected distance visual acuity and delays myopia progression in myopic children, though no significant visual improvement is observed in non-myopic children. The combine “balance training + visual task” intervention effectively enhances both static and dynamic balance in children, offering dual benefits of improving motor function and delaying myopia progression. It is recommended that elementary school PE classes incorporate an appropriate amount of “balance + visual” compound training each week, as the protocol is simple to implement. Future research should extend the intervention duration, include follow-up measurements, enroll children of different ages and with varying degrees of myopia, and incorporate objective measures such as axial length to further validate the intervention effects.

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Conflicts of Interest

The authors declare no conflict of interest.

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