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ORIGINAL RESEARCH

Effectiveness and safety of Nintendo Wii Fit Plus™ training in children with migraine without aura: a preliminary study

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Background: Migraine without aura (MoA) is a painful syndrome, particularly in childhood; it is often accompanied by severe impairments, including emotional dysfunction, absenteeism from school, and poor academic performance, as well as issues relating to poor cognitive function, sleep habits, and motor coordination.

Materials and methods: The study population consisted of 71 patients affected by MoA (32 females, 39 males) (mean age: 9.13±1.94 years); the control group consisted of 93 normally developing children (44 females, 49 males) (mean age: 8.97±2.03 years) recruited in the Campania school region. The entire population underwent a clinical evaluation to assess total intelligence quotient level, visual-motor integration (VMI) skills, and motor coordination performance, the later using the Movement Assessment Battery for Children (M-ABC). Children underwent training using the Wii-balance board and Nintendo Wii Fit Plus™ software (Nintendo Co, Ltd, Kyoto, Japan); training lasted for 12 weeks and consisted of three 30-minute sessions per week at their home.

Results: The two starting populations (MoA and controls) were not significantly different for age (P=0.899) and sex (P=0.611). M-ABC and VMI performances at baseline (T0) were significantly different in dexterity, balance, and total score for M-ABC ($P<0.001$) and visual (P=0.003) and motor ($P<0.001$) tasks for VMI. After 3 months of Wii training (T1), MoA children showed a significant improvement in M-ABC global performance ($P<0.001$), M-ABC dexterity ($P<0.001$), M-ABC balance ($P<0.001$), and VMI motor task ($P<0.001$).

Conclusion: Our study reported the positive effects of the Nintendo Wii Fit Plus™ system as a rehabilitative device for the visuomotor and balance skills impairments among children affected by MoA, even if further research and longer follow-up are needed.

Keywords: childhood rehabilitation, pediatric migraine, migraine without aura, Nintendo Wii Fit Plus™

Introduction

Migraine without aura (MoA) could be considered common during the pediatric age, with a prevalence ranging from 2% to 17%.[1,2] MoA is not just a painful condition, it is often accompanied by comorbidities that may lead to significant disability.[3] In fact, children and adolescents affected by MoA could present a higher rate of low emotional and psychological functioning,[4] familiar stress,[5–8] school absenteeism, impairment of academic performance and cognitive functioning,[9] impaired motor coordination,[10] and disturbed sleep habits,[11–17] and lower physical activity levels.[18,19]

As a result of the debilitation effects of MoA, in clinical pediatric practice, and in association with pharmacological treatment,[20] many alternative therapies have been explored. Some have shown promise in the treatment of headache symptoms

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and/or comorbidities in affected children, such as weight loss,[21] nutraceuticals,[22–24] sleep hygiene,[25,26] psychotherapy, and generic psychological interventions.[27–30] Moreover, in a previous study we have reported the higher prevalence of motor problems and balance impairment with respect to the control group.[10]

In this light, an intriguing new trend in clinical literature has suggested the use of exergames (entertaining video games that combine game play with exercise) and/or virtual reality systems for use in the neurological rehabilitation of patients of all ages.[31–35] The use of gaming technology in the rehabilitative setting has seen an unprecedented rise in recent years; many and varied are the application of exergames, including promoting physical activity, balance improvement, and motor coordination[36,37] in those with or without disabilities,[38,39] for childhood neuromotor impairments, for those with cerebral palsy,[38–44] and/or for balance alterations.[39,41,42,44–47]

The Nintendo Wii Fit Plus™ system (Nintendo Co, Ltd, Kyoto, Japan) is an off-the-shelf, low cost gaming console originally designed for the general population for gaming/entertainment purposes. The system consists of an inexpensive interface device (web camera or accelerometer) allowing the user's interaction with the virtual objects in a competitive game environment displayed on a standard television screen. The games are designed to be fun and interactive, provide activities for a variety of age groups, and have built-in motivational features such as score keeping and video playbacks. The use of interactive video gaming has been identified as a possible strategy to also improve motor performance. Low-cost motion-interactive games may provide increased motivation and social interaction to home training and they may promote independent training, with reduced coaching efforts for parents. In fact, in future design of interactive games for the purposes of rehabilitation, it is important to preserve both the motivational and the social features of games while optimizing the individualized physical exercise.[48]

Moreover, due to the complexity of tasks that involve cognitive stimulation as well as motor skills, the Nintendo Wii Fit Plus™ system could promote improved integration of motor and cognitive abilities that, when compared with balance exercise training based on motor stimulation alone, could contribute to increased independence in daily life.[49]

We hypothesized that a short-term exercise program would be effective in improving the balance and the gross motor coordination in a cohort of children and adolescents affected by MoA. To date, no data are available on exercise training programs involving a sample of children and adolescents with MoA; thus, this study aimed to conduct a clinical trial to evaluate the feasibility and effectiveness of self-efficacy-based intervention using Wii exergames for the balance rehabilitation in children with MoA.

Materials and methods

MoA was diagnosed according to the International Classification of Headache Disorders (ICHD-3) criteria.[50]

The study population consisted of 71 patients affected by MoA (32 females, 39 males) (mean age: 9.13±1.94 years), consecutively referred to the tertiary level Center for Childhood Headache (Department of Child and Adolescent Neuropsychiatry, Second University of Naples). The control group consisted of 93 normally developing children (44 females, 49 males) (mean age: 8.97±2.03 years) recruited in the Campania school region. Children were included if they had access to a Nintendo Wii Fit Plus™ system at home.

Exclusion criteria included any of the following: allergies; endocrinological problems (ie, diabetes); genetic syndromes (eg, Down syndrome, Sturge–Weber syndrome, neurofibromatosis);[24,51] if the subject was a preterm birth;[52,53] neurological issues (eg, epilepsy, all types of headache other than MoA); psychiatric symptoms (attention deficit hyperactivity disorder, depression, behavioral problems); intellectual disability (IQ ≤70); previous rehabilitative treatment;[54] borderline intellectual functioning (IQ ranging from 71 to 84);[55,56] if the subject was overweight (body mass index [BMI] ≥85th percentile) or obesity (BMI ≥95th percentile);[57,58] sleep disorders;[11,17,26,59–61] primary nocturnal enuresis;[15,62,63] and anticonvulsant[64,65] or psychoactive drug administration.

The subjects in both groups were recruited from the same urban area; participants were all Caucasian and were of a middle-class socioeconomic status (between class 2 or class 3 – corresponding to 28,000–55,000 euros/year to 55,000–75,000 euros/year, respectively – according to the current Italian economic legislation parameters).

The Departmental Ethics Committee approved the study. The study was conducted according to the criteria of the Declaration of Helsinki.[66]

Movement Assessment Battery for Children

The impairment of motor coordination performance relative to age expectations was determined using the Movement Assessment Battery for Children (M-ABC). This test is frequently used in both clinical and research settings to assess children for a Developmental Coordination Disorder (DCD) and has high reliability and validity.[67] The test assesses fine and gross motor skills using three manual dexterity tasks, two ball skills tasks, and three balance tasks, each of which is scored on a five-point scale. The raw score of each item is then converted to a score scale ranging from zero to five. A higher score indicates a less-than-adequate performance. Consequently, 0 reflects a complete success by the candidate on the task examined, while 5 reflects a failure in the execution of the task; failed (F), inappropriate (I), and refused (R) performances are all assigned a transformed score of 5.

The sum of the eight scores corresponds to the total score for disability, with a range of between 0 and 40, wherein a lower score is a result of a child implementing the best possible moves. The content of the items differs depending on the age of the child examined, with increasing difficulty according to age, so that the battery is made up of four different types of activities considered to be made in relation to age (4–6 years, 7–8 years, 9–10 years, and 11–12 years). Each subject was assessed individually for about 20–40 minutes.[67] The total impairment score was calculated from these individual tasks and was used to generate a percentile score compared to the standardization sample. Consistent with a recently published meta-analysis,[68] in this study a child was considered to have a DCD if the total score was less than or equal to the fifth percentile, and a borderline motor impairment if the total score was less than or equal to the fifteenth percentile.

Developmental test of visual-motor integration.

Fine motor coordination and visual motor integration were assessed with the Beery visual-motor integration. (VMI) task,[69] a paper-and-pencil test where children have to imitate or copy up to 27 geometric forms with increasing complexity using paper and pencil. The test was stopped when a child made more than two errors in a row. Copying errors were marked if they reflected problems in fine motor coordination, rather than pure visuospatial problems. The task is specifically designed for children and takes about 10 minutes. The Beery VMI scores were standardized for age and sex using normative data for the Italian general population.[69] The percentile scores were used for diagnosing the visual-motor abnormalities in our sample, and a value less than the fifth percentile was considered to mean a visual-motor integration impairment.

Training

The MoA and Control groups were trained at their homes on the Wii balance board and the Nintendo Wii Fit Plus™ software. Training consisted of three 30-minute sessions per week, for a period of 12 weeks.

The Nintendo Wii Fit Plus™ Console and games were utilized in conjunction with a standard television set. Games used were divided into categories based on the primary direction of weight shift required to perform the task successfully. Thus, games included under each category were as follows: antero-posterior (snowboarding); medio-lateral (skiing, penguin game, and soccer); and multidirectional weight shifting (bubble game and hula hoop). As previous reported, all games incorporate balance and coordination training and most include feedback related to both knowledge of results (auditory) and knowledge of performance (visual).[70]

Prior to the intervention, each child performed a balance-test on the Wii-balance board to determine the appropriate difficulty level. This test has been validated (test–retest reliability within-device: intraclass correlation coefficient [ICC] =0.66–0.94; between-device: ICC =0.77–0.89) in comparison with a force platform.[71] During each session, the children chose between 18 balance games such as ski-jump, segway circuit, obstacle course, and skate boarding. The games were selected for the training program because they all appealed to the children's ability to adjust their center of gravity in a different way. All games challenged the user to actively change their center of gravity, although there was a difference in direction and amount of displacement to generate an effect. In particular, ski-slalom, table tilt, and snowboard slalom are based on more dynamic balance skills, whereas the games Tilt City and Rhythm induce a more static balance skill. In addition, users received various direct visual feedback on a TV screen to implicitly regulate their balance based on sensory information. For instance, the snowboard-slalom appealed to balance regulation by eliciting repeated sideways displacement of weight. These displacements were visible as a skier on the screen who moved accordingly around the slalom poles. Furthermore, the games all provided for limitless exercises, visual feedback, and motivational reinforcement by presenting rewards such as new games and points. To induce sufficiently varied training, users had to choose three to five games each session. Every session and game-duration was automatically logged into the Wii system. Based on this information, the trainers guided the children to practice all 18 balance games.

During the intervention the difficulty levels were automatically adjusted depending on the skill-growth of the children; this resulted in better game scores.[45]

Statistical analysis

In order to compare the two starting populations, Student's *t*-test and chi-square test analysis, where appropriate, were applied. Subsequently, for VMI and M-ABC evaluation between baseline (T0) and after 12 weeks of training (T1), the paired *t*-test was applied for the MoA and Control groups. $P \leq 0.05$ was considered to be statistically significant.

The commercially available STATISTICA software (StatSoft Inc., Tulsa, OK, USA) was used for statistical evaluation.

Results

The two starting populations (MoA and Controls) were not significantly different for age ($P=0.899$) and sex ($P=0.611$). M-ABC and VMI performances in the two groups at baseline (T0) were significantly different in dexterity, balance and total score for M-ABC ($P<0.001$), and visual ($P=0.003$) and motor ($P<0.001$) tasks for VMI (Table 1).

After 3 months of Wii training (T1) MoA children showed a significant improvement in M-ABC global performance ($P<0.001$), M-ABC dexterity ($P<0.001$), M-ABC balance ($P<0.001$) and VMI motor task ($P<0.001$); meanwhile, Control children showed no significant improvement in M-ABC and VMI performances (Tables 2 and 3).

M-ABC performances of the two groups at T1 were significantly different in dexterity ($P=0.006$), balance ($P=0.020$), and total score ($P=0.006$); VMI performances at T1 were not significantly different between the two groups (Table 4).

Table 1 Comparison of children affected by MoA and typical developing subjects (Controls) for the motor and visuomotor skills at baseline (T0)

	MoA (n=71)	Controls (n=93)	*P*-value
M-ABC dexterity	4.993±2.788	2.425±2.338	<0.001
M-ABC ball skills	1.930±1.254	1.785±1.417	0.497
M-ABC balance	2.965±1.755	1.532±1.584	<0.001
M-ABC total score	9.887±4.002	5.742±3.099	<0.001
M-ABC percentile	20.901±19.753	43.355±23.432	<0.001
VMI total score	31.408±16.679	33.882±21.335	0.421
VMI visual task	52.493±24.122	63.697±23.233	0.003
VMI motor task	5.493±3.847	20.703±20.190	<0.001

Notes: Student's *t*-test was applied. *P*≤0.05 was considered statistically significant.
Abbreviations: MoA, migraine without aura; n, number; M-ABC, Movement Assessment Battery for Children; VMI, visual-motor integration.

Table 2 Comparison of children affected by MoA for the motor and visuomotor skills at baseline (T0) and after 3 months (T1) of Nintendo Wii Fit Plus™ home training

	MoA group at T0 (n=71)	MoA group at T1 (n=71)	*P*-value
M-ABC dexterity	4.993±2.788	2.768±2.430	<0.001
M-ABC ball skills	1.930±1.254	1.845±1.390	0.704
M-ABC balance	2.965±1.755	1.725±1.360	<0.001
M-ABC total score	9.887±4.002	6.338±3.443	<0.001
M-ABC percentile	20.901±19.753	39.606±23.855	<0.001
VMI total score	31.408±16.679	35.197±21.488	0.243
VMI visual task	52.493±24.122	58.152±25.181	0.174
VMI motor task	5.493±3.847	22.390±21.670	<0.001

Notes: Paired Student's *t*-test was applied. *P*≤0.05 was considered statistically significant. Nintendo Wii Fit Plus™, Nintendo Co, Ltd, Kyoto, Japan.
Abbreviations: MoA, migraine without aura; n, number; M-ABC, Movement Assessment Battery for Children; VMI, visual-motor integration.

Table 3 Comparison of typical developing subjects (Controls) for the motor and visuo motor skills at baseline (T0) and T1 (after 3 months) of Nintendo Wii Fit Plus™ home training

	Controls T0 (n=93)	Controls T1 (n=93)	*P*-value
M-ABC dexterity	2.425±2.338	1.973±1.084	0.094
M-ABC ball skills	1.785±1.417	1.594±1.106	0.307
M-ABC balance	1.532±1.488	1.306±0.912	0.204
M-ABC total score	5.742±3.099	4.931±2.968	0.070
M-ABC percentile	43.355±23.432	41.094±21.613	0.495
VMI total score	33.882±21.335	35.128±19.994	0.682
VMI visual task	63.697±23.233	65.014±22.011	0.692
VMI motor task	20.703±20.190	21.764±18.466	0.709

Notes: Paired Student's *t*-test was applied. *P*≤0.05 was considered statistically significant. Nintendo Wii Fit Plus™, Nintendo Co, Ltd, Kyoto, Japan.
Abbreviations: MoA, migraine without aura; n, number; M-ABC, Movement Assessment Battery for Children; VMI, visual-motor integration.

Table 4 Comparison of children affected by MoA and typical developing subjects (Controls) for the motor and visuomotor skills at T1 (after 3 months) of Nintendo Wii Fit Plus™ home training

	MoA (n=71)	Controls (n=93)	*P*-value
M-ABC dexterity	2.768±2.430	1.973±1.084	0.006
M-ABC ball skills	1.845±1.390	1.594±1.106	0.200
M-ABC balance	1.725±1.360	1.306±0.912	0.020
M-ABC total score	6.338±3.443	4.931±2.968	0.006
M-ABC percentile	39.606±23.855	41.094±21.613	0.677
VMI total score	35.197±21.488	35.128±19.994	0.983
VMI visual task	58.152±25.181	65.014±22.011	0.065
VMI motor task	22.390±21.670	21.764±18.466	0.842

Notes: Student's *t*-test was applied. *P*≤0.05 was considered statistically significant. Nintendo Wii Fit Plus™, Nintendo Co, Ltd, Kyoto, Japan.
Abbreviations: MoA, migraine without aura; n, number; M-ABC, Movement Assessment Battery for Children; VMI, visual-motor integration.

Discussion

The main finding of the present study is the demonstration of the safety and efficacy of the Nintendo Wii Fit Plus™ system to improve the balance and the gross motor function in MoA children.

Moreover, a growing body of research has demonstrated a link between physical activity and the health of brain structure and function.[72–74]

Computers and electronic games have become an important part of the daily activities among school-aged children and adolescents – this is a worldwide trend.[75] Additionally, training studies have demonstrated that significant improvements in visuospatial cognition are observed with as little as 10 hours of videogame training,[76,77] suggesting that videogames may provide an effective therapeutic platform in individuals and groups that possess lower levels of visuospatial abilities.[76,78] Our findings about improvements in the motor skills in children with MoA ($P<0.001$) could support these data.

The Nintendo Wii Fit Plus™ is one of the most popular health video games and has been broadly used in senior centers and retirement communities.[79] Empirical evidence supports that using Wii exergames as an intervention in older adults can maintain and/or improve physical functions such as balance, mobility, strength, flexibility,[80] and balance confidence.[81] Many reports have shown that children with motor problems typically display increased amounts of postural sway in static balance.[82] As a result, effective interventions have been developed to overcome this difficulty.[83] In general however, less attention has been paid to dynamic balance problems, despite the fact that these children have considerably more problems in maintaining dynamic balance.[84]

The integration of virtual reality into neurorehabilitation is an approach to therapy that is currently being explored in both adults and children with promising results. In fact, it has been shown that neurons in the adult human brain can increase their firing rates when the individual observes movements being performed by another person.[85,86] Moreover, the activation of the mirror–neuron system can induce cortical reorganization and possibly contribute to functional recovery. Virtual reality gaming systems such as the Nintendo Wii™ are simple, not expensive, and could potentially be a treatment option for supporting children engaged in rehabilitation processes in their homes. The most important strength of our study could be considered the improvement in visuomotor skills obtained by this home therapy with 100% of compliance and the absence of illness perception by children linked to the rehabilitation center sessions.

Nintendo Wii Fit Plus™ training has been identified as a promising tool to support children with motor coordination problems,[87] such as those present in children with MoA. Moreover, the Nintendo Wii incorporates aspects of biofeedback and virtual reality which, when used as a form of motor rehabilitation, can improve motivation to exercise,[88] exercise tolerance[89] and motor performance among children with Down's Syndrome[90] and cerebral palsy.[42] In a recent study by Hammond et al,[91] the authors reported gains in motor proficiency and perception of motor ability among children with a DCD who received training on the Nintendo Wii. Improvement in motor activity domains that were not specifically practiced (ie, fine motor precision) was also reported, suggesting that the Nintendo games may help to develop broader motor coordination skills;[91] these findings are supported by our own results, which showed improvements in balance ($P<0.001$) and dexterity ($P<0.001$) abilities in MoA children after 3 months of Nintendo Wii Fit Plus™ training. Additionally, video game interventions can increase patient enjoyment and engagement, which may enhance compliance.[92]

Finally, we have to take into account some limitations in the present preliminary study. Firstly, we did not consider the clinical characteristics of MoA (eg, frequency and pain intensity) because we have focused on the visuomotor coordination skills and balance rehabilitation (reported in the interictal periods). Secondly, we must note the brief duration of the follow-up.

Conclusion

In conclusion, our study reported the positive effects of the Nintendo Wii Fit Plus™ system as a rehabilitative device for visuomotor and balance skills impairments among children affected by MoA, even if further research and longer follow-up are needed.

Disclosure

The authors report no conflicts of interest in this work.

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