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Time for change: Fitness and strength can be improved and sustained in adolescents with low motor competence

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Time for change: Fitness and strength can be improved and sustained in adolescents with low motor competence

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ABSTRACT

Background: There are few exercise interventions focused on adolescents with low motor competence and most interventions are short with little follow up and engagement over time.
Methods and procedures: Fifty-eight adolescents with low motor competence (39 males, $M_{ean\ Age}$ = 13.6, SD = 1.4 years) attended an exercise clinic twice a week for each 13 week program. Two programs ran each year, and participants attended for as long as they felt progress was made or they turned 18 years of age. Performance on the Multistage Fitness Test (MSFT), Curl-ups, Grip Strength, 1RM Leg press and Chest Press, Vertical Jump and Standing Broad Jump (SBJ) were recorded pre and post each program for up to six years.

Linear Mixed Modelling (LMM) determined changes in fitness measures over time whilst adjusting for gender, age and Neuromuscular Developmental Index (McCarron, 1997).
Results: All fitness measures increased, and specifically four of the seven fitness outcomes showed significant improvement over time (MSFT, $p = 0.011$; curl-ups, $p < 0.001$, grip strength $p = 0.003$, and SBJ $p = 0.006$).
Conclusion: An individually tailored regular exercise program in a supportive environment can achieve exercise adherence and sustainable improvements in fitness outcomes for adolescents with low motor competence. Future research should consider the addition of a comparison LMC control group to increase understanding of the intervention effect.

What this paper adds:

Previous research has not provided clear strategies for exercise interventions to improve fitness in adolescents, particularly those with low motor competence. This paper adds important knowledge to the limited research on exercise programs for these adolescents. Exercise programs that are long term, individually focused, supportive and developmentally appropriate can deliver positive and sustained fitness improvements for adolescents with low motor competence. Importantly, adolescents may then commit to long term programs and maintain health benefits.

1. Introduction

Poor physical health outcomes for children and adolescents with low motor competence (LMC) has been an area of interest over many years (Rivilis et al., 2011). Children and adolescents with LMC, who may be clinically diagnosed with Developmental Coordination Disorder (DCD), participate in less daily physical activity than their well-coordinated peers (Green et al., 2011; Rivilis

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et al., 2011) and for many, physical fitness can be compromised (Hands & Larkin, 2002, 2006; Tsiotra et al., 2009). Both cross sectional (Cairney et al., 2010; Cairney, Hay, Veldhuizen, & Faught, 2011; Hay, Faught, & Cairney, 2010) and longitudinal studies (Joshi et al., 2015) have also reported associations between poor motor proficiency and a higher percentage body fat. Consequently, low activity and fitness levels can contribute to an increase in the risk of associated health issues such as cardiovascular disease (Coverdale et al., 2012; Faught, Hay, Cairney, & Flouris, 2005). Given that LMC can persist into adolescence and adulthood (Cantell, Crawford, & Doyle-Baker, 2008; Cousins & Smyth, 2003; Kirby, Edwards, & Sugden, 2011), and physical fitness components such as cardiorespiratory fitness, power and muscle strength are important for health (Rivilis et al., 2011), effective evidence-based exercise interventions suitable for these maturing populations are needed (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012).

Reviews of interventions designed to improve a variety of motor outcomes have primarily involved younger children and generally report a range of approaches (Hillier, 2007; Pless & Carlsson, 2000; Smits-Engelsman, Blank, Van Der Kaay, Mosterd-Van der Meijs, & Vlugt-Van den Brand, 2012; Smits-Engelsman et al., 2018). Smits-Engelsman et al. (2018) recent systematic review identified 30 studies with children (aged 4–12 years) that reported an evaluation of motor-based interventions. When specifically examining health related fitness outcomes, they concluded that moderate-to-strong improvements were found across a variety of motor interventions, whether Task oriented, General Skill training, or Sport/Play related Skill focused. Most interventions reviewed were short term with little long term follow-up information or ongoing engagement by participants (Hillier, 2007; Pless & Carlsson, 2000; Smits-Engelsman et al., 2012; Smits-Engelsman et al., 2018). There are also few interventions that have specifically targeted adolescents and adults and health related outcomes. Overall, little is known about the sustainability of interventions and consideration needs to be given to the type and length of interventions for adolescents with LMC.

Several factors must be considered for exercise program design for an adolescent population. The program should aim to be developmentally appropriate from both physical and social perspectives given the physical and emotional changes that occur with puberty (Faigenbaum & Myer, 2010) and the growing influence of peers (Fitzgerald, Fitzgerald, & Aherne, 2012). For Australian adolescents, physical fitness components are typically developed and maintained by participation in sports such as soccer, basketball or netball (Hands, Parker, Glasson, Brinkman, & Read, 2004). However, these sports are competitive, complex and occur in mobile, unpredictable environments. Thus the level of required skill precludes the involvement of adolescents with LMC as they tend to show more variable and inefficient movement patterns (King, Harring, Oliviera, & Clark, 2011; Smits-Engelsman, Neimeijer, & Van Galen, 2001) and display difficulty in executing skills in a moving, unstable environment, such as these competitive team sports. They need to first master the basic motor skills in a stable environment without the complexity of opposition players and teammates, trying to anticipate where a ball may come from, or remembering what team strategy should be put into play. Therefore, individually designed activities in predictable environments and which build on principles of motor control and learning are most likely to be effective for adolescents with LMC.

A supervised exercise program in a fitness gymnasium provides such a setting. In this closed environment adolescents can exercise on equipment that constrains their limbs to move in efficient and effective patterns so that a specific muscle or muscle group can be used. As a result, exposure to such a program may develop physical fitness components (such as cardiorespiratory, muscle and abdominal strength) and capabilities to improve physical health outcomes and engage in exercise over a period of time. The purpose of this study was to examine changes in fitness and strength outcomes in adolescents with LMC after participating in an individually designed exercise program over time.

2. Methods

This study employs a repeated measures longitudinal research design to examine changes in fitness outcomes over time in adolescents with low motor competence.

2.1. Participants

Fifty eight (N = 58) participants, 39 males and 19 females, aged between 13 and 17 years ($M = 13.6$, $SD = 1.4$) attended a university based exercise clinic twice per week for 90 min over a 13 week program, twice a year. Participants were recruited through allied health professional contacts, word of mouth, and the distribution of information flyers, electronically and by hard copy.

Program eligibility included being aged between 13 and 17 years, and a Neuromuscular Developmental Index (NDI) score of ≤ 85 derived from the McCarron Assessment of Neuromuscular Development (MAND) (McCarron, 1997) that indicated a motor disability. This assessment was undertaken by the primary researchers who have between 20 and 30 years' experience working with this population. An applicant with a NDI over 85 could still be accepted into the program if the parents reported a history of movement difficulties (such as clumsiness, slowness and inaccuracy of motor skills that negatively impacted daily living, school, leisure or play activities). Applicants were ineligible for the program if unable to follow instructions or self-ambulate. Participants attended the program for as many semesters as necessary or until they turned 18 years of age.

2.2. Intervention

The Adolescent Movement Program (AMPitup) is located in an exercise clinic at a University in Perth, Australia. Between 20 and 25 participants attend two sessions per week, for 13 weeks per program. Each session is 90 min. Two programs run each year with a break for seven weeks in the middle of the year, and 17 weeks at the end of the year over summer. Each participant is paired with a 3rd year undergraduate student trainer enrolled in an Exercise and Sport Science or Physiotherapy degree or a 4th year postgraduate student enrolled in a Clinical Exercise Physiology degree. These students have completed several units of study regarding exercise prescription and attend a pre-intervention 2 h information session. Each trainer designs an individually focussed program involving cardiorespiratory fitness, resistance training, and motor skill techniques based on a discussion with the participant regarding their interests and needs. Following each session participants also provide feedback to their trainer on specific goals for the next session. Each session is planned by the trainer and recorded in a booklet. For example, the number of sets, repetitions, and weight is recorded for all pin-loaded machines and free weights. Progression across the program of increasing sets, repetitions and weight is determined by the trainer. Four set exercises; leg press, chest press, plank, and a five minute cardiovascular exercise are completed each session to enable consistent tracking of progress. For the cardio exercise, the trainer and participant decide together which equipment (recumbent bike, cross trainer, cycle ergometer or rowing ergometer) to use (McIntyre et al., 2015). The program is overseen by one of the primary researchers and an Accredited Exercise Physiologist.

2.3. Measures

2.3.1. Motor competence

Initial screening of motor competence was assessed using the MAND (McCarron, 1997), a ten item test battery that derives an age and sex appropriate score for motor development, the Neuromuscular Development Index (NDI). Raw scores from each task were converted to scaled scores ($M = 10$, $SD = 3$) using a table of norms and the NDI ($M = 100$, $SD = 15$) was then calculated. An NDI score one standard deviation below the mean (< 85) is considered to be indicative of motor dysfunction (McCarron, 1997). The test has evidence of validity and reliability with an Australian population and the target age group (Hands, Larkin, & Rose, 2013; McCarron, 1997).

2.3.2. Fitness and strength measures

Seven fitness measures were recorded before and after each 13-week program. These measures were taken by the primary researchers, or for some measures, by the trainers. The trainers received training on protocol for all measures they recorded.

2.3.2.1. Cardiorespiratory fitness. The multi-stage fitness test (MSFT) (Leger & Lambert, 1982) was used to measure cardiorespiratory fitness. The test required participants to run between two points, set 20 m apart, keeping in time with a pre-recorded audio sound that beeps at set intervals. At the first level the beeps are recorded to coincide with a pace of 8.5 km/hr. Each stage increases this pace by 0.5 km/hr, with each requiring a number of runs in order to complete the stage. Once the participant is unable to maintain the set pace, their score was recorded as the last completed shuttle.

2.3.2.2. Abdominal strength. Participants were required to complete as many curl-ups as they could, with correct technique, to a pre-recorded cadence over a maximum of three minutes (Australian Council for Health Physical Education & Recreation, 1996). In a supine position, with knees bent at approximately 90 degrees and feet flat on the floor, participants were instructed to keep their arms straight and closed fists, resting on their thighs. At the sound of each cadence they lift their upper body off the floor and touch a ruler held by the instructor at the top of their knees. The total number of curl ups was recorded to a maximum of 80 or until the participant was unable to maintain correct form.

2.3.2.3. Grip strength. Grip strength was measured with a hydraulic hand dynamometer (Dynamometer, Therapeutic Instruments Clifton N.J.) using the test protocol outlined by the MAND (McCarron, 1997). Participants stand, feet shoulder width apart, with their arm holding the dynamometer down at their side. As they raise their arm to shoulder height in front of their body they squeeze the dynamometer as hard as possible. Two trials are performed for each hand and the highest values (kg) combined for a total score.

2.3.2.4. Chest strength. Chest strength was recorded by a one repetition maximum (1RM) seated chest press on a pin-loaded independent chest press machine (SportsArt Fitness). Prior to completing the 1RM test, participants complete a light warmup and stretch. Protocol for the 1RM includes an initial 6–10 repetitions with a relatively light load (based on participant feedback and exertion). The load is then increased slightly and participants are asked to complete 3–6 repetitions. They then perform a series of single repetitions with heavier loads if the previous repetition is completed with correct technique. The increment of weight increase is dependent on the effort required by the participant on the previous repetition. Their 1RM is recorded as the maximum resistance that is completed with a full range of motion and correct form.

2.3.2.5. Leg strength and power. Leg strength and power was measured in three ways, the 1RM leg press on a pin-loaded leg press machine (SportsArt Fitness), Standing Broad Jump and Vertical jump. The protocol for the 1RM Leg press is the same as the Chest press described above.

The Standing Broad Jump (SBJ) (McCarron, 1997) is performed standing with both feet together behind a line adjacent to a measuring strip. They jump as far as possible and the distance noted to the heels at the landing point. The best of three jumps (in inches) is recorded. The vertical jump (VJ) is measured using a Vertec vertical jumping device (Swift Performance Equipment, Lismore, Australia). The participants stand with both feet flat on the ground, raise their arms and displace the highest vane possible from a standing position. They then jump from a stationary position to displace the highest vane they can. The number between the standing and jumping vanes is recorded as their VJ score.

Table 1
Summary statistics for each fitness measure at baseline and on the last measured occasion.

Fitness Measure	Baseline		Last measurement		Pre-Post*
	Mean (SD)	Median	Mean (SD)	Median	p-value
MSFT (shuttles)	22.4 (14.5)	18.0	31.9 (18.0)	31.5	< **.001**
Vertical Jump (cm)	27.0 (8.8)	27.0	31.7 (10.2)	32.0	< **.001**
Curl ups (count)	16.4 (11.1)	14.0	42.1 (26.1)	35.0	< **.001**
Standing Broad Jump (cm)	48.5 (14.6)	49.0	55.0 (14.2)	57.0	< **.001**
Grip Strength (Nm)	40.0 (14.1)	37.0	53.8 (17.0)	53.0	< **.001**
1RM Leg Press	70.0 (33.3)	60.0	119.6 (49.5)	130.0	< **.001**
1RM Chest Press	26.2 (16.4)	21.5	47.8 (23.5)	40.0	< **.001**

Note. * Wilcoxon Signed Rank Test reported.
Bold indicates Bonferroni corrected statistical significance p < .007.

2.3.3. Data analysis

The statistical software IBM SPSS version 24 (IBM Corp, 2016) was used for all statistical processes with statistical significance set $p < .05$. Descriptive demographics are reported (Table 1). Fitness measures were taken pre and post each semester program, however we have not reported fitness data for each occasion as the focus was on changes over time. Instead summary statistics are firstly provided for the first and last data collection point with a Wilcoxon Signed Rank Test used to examine the difference between the first and last time point for each fitness measure.

Linear Mixed Modelling (LMM) with Bonferonni post-hoc analyses were then used to examine fitness outcomes over time. This type of analysis permits flexible time-varying measures accounting for within-person and between-person changes, is more flexible than repeated measures ANOVA in fitting and testing covariance structures, permits individuals to have missing data points (missing at random), and allows for the inclusion of time-varying factors as well as the time measurement (West, Welch, & Galecki, 2015). Each fitness measure was treated as a separate dependent variable model. Participant ID was treated as a random effect, with an autoregressive covariance structure employed. Gender, age (at each test occasion) and NDI were evaluated within each model as fixed effects. The time varying covariate was test occasion, measured as a count from one to 20, representing pre and post measures for each semester program in consecutive numerical order. Final model residuals were visually checked and met the assumption for normality for each fitness measure model.

3. Results

The majority of participants (88.9%) completed at least 16 out of the 26 sessions for each 13 week program ($M = 20.6$, $SD = 3.4$), and overall attended an average of 5.8 programs (3 years). Participants had a mean age of 13.6 years (SD = 1.4), had a mean weight of 67.3 kg ($SD = 16.7$), mean height of 168.9 cm ($SD = 9.7$), mean BMI of 23.4 ($SD = 4.4$) and mean waist circumference of 81.7 cm ($SD = 12.3$) at their first occasion of testing. Summary statistics are described for each of the fitness measures at baseline and on the last measured occasion with significant differences reported for all fitness measures (Table 1).

Adjusting for gender, age and NDI, LMM analysis found four of the seven fitness measures showed significant improvement over time, these were the MSFT ($p < .001$), curl ups ($p < .001$), SBJ ($p = .006$) and grip strength ($p = .003$) (Table 2). Although not statistically significant, the estimates for all remaining fitness measures depicted improvement over time. The LMM predicted values for each fitness measure are depicted in Fig. 1 and show the adjusted changes over time up to the 20th time point.

4. Discussion

Overall, adolescents with movement difficulties participating in the exercise program improved their fitness. Ongoing participation in our exercise program led to better fitness outcomes. The improvements in all measures over time (four of which were significant) were a focus of the set exercises each session as well as the prescribed activities incorporated by the trainers. For example aerobic fitness (measured by the MSFT) is developed through regular time spent on one or more of the ergometers, including the treadmill, cross trainer, or stationary bike as well as outside running. Abdominal strength (measured by Curl ups) is built through the plank exercise and several of the pin loaded machines. The chest and leg press are also set exercises and the skill of jumping is deliberately incorporated into different games and activities by the trainers. It is also important to note these changes over time are maintained despite breaks (7 and 17 weeks respectively) between the delivery of each program.

The observed improvements could also be attributed to the design of the exercise equipment. Most pieces of equipment constrain a participant's movement so that only specific muscle groups such as the abdominals are involved. This is difficult with these participants in open, unconstrained environments such as floor or game based exercises where inefficient movement results in poor skill performance. Adolescents with LMC have difficulty generalizing skilled performances from one situation to another (Missiuna, Rivard, & Pollock, 2011). They do not recognize similarities in movement pattern similarities, for example between the vertical jump and the SBJ (Missiuna et al., 2011). Most equipment in a gym setting minimises complex coordination demands that these adolescents experience in open, changeable skill environments.

Table 2
Linear Mixed Model results for each fitness measure.

Model	Variable	Estimate (β)	SE	p-value
MSFT	*Intercept*	*6.58*	*16.4*	*.690*
	Gender (male)[a]	5.63	3.21	.085
	NDI	0.54	0.08	< **.001**
	Age	−0.08	0.09	.380
	Time	1.25	0.30	< **.001**
Vertical Jump	*Intercept*	*20.13*	*10.21*	*.053*
	Gender (male)[a]	2.52	1.97	.208
	NDI	0.31	0.05	< **.001**
	Age	0.14	0.06	**.017**
	Time	0.30	0.18	0.103
Curl Ups	*Intercept*	*0.71*	*24.91*	*.977*
	Gender (male)[a]	8.00	4.67	.094
	NDI	0.54	0.12	< **.001**
	Age	−0.10	0.14	.486
	Time	2.71	0.47	< **.001**
Standing Broad Jump	*Intercept*	*3.37*	*15.1*	*.825*
	Gender (male)[a]	5.16	3.05	.097
	NDI	0.45	0.08	< **.001**
	Age	0.05	0.08	.528
	Time	0.72	0.26	**.006**
Grip Strength	*Intercept*	*44.34*	*16.45*	*.009*
	Gender (male)[a]	6.24	3.23	.059
	NDI	0.39	0.08	< **.001**
	Age	0.32	0.09	**.001**
	Time	0.89	0.29	**.003**
1RM Leg Press	*Intercept*	*144.38*	*62.84*	*.026*
	Gender (male)[a]	10.62	10.58	.322
	NDI	0.91	0.28	**.003**
	Age	0.99	0.37	**.010**
	Time	1.38	1.22	.261
1RM Chest Press	*Intercept*	*103.07*	*33.50*	*.003*
	Gender (male)[a]	6.03	5.54	.285
	NDI	0.40	0.15	**.012**
	Age	0.60	0.20	**.004**
	Time	0.31	0.65	.634

[a] Female is the comparison group and is redundant and set to zero. Note: Time was measured as a count of test occasions. **Bold** indicates statistical significance $p < .05$. *Italics* specifies the intercept values for the model.

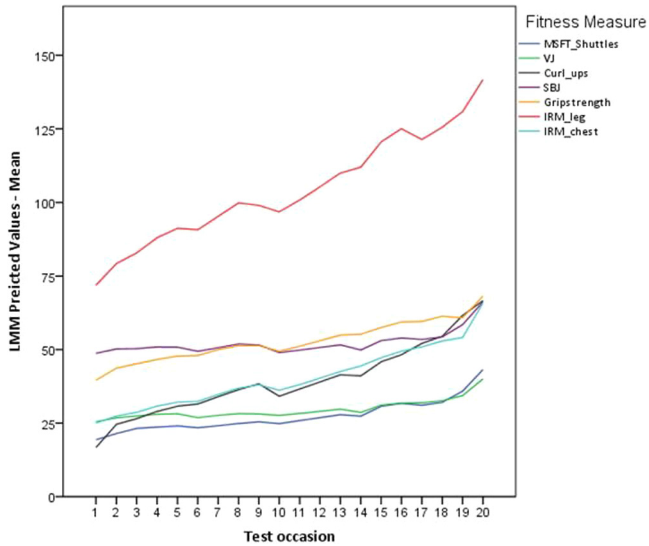

Fig. 1. LMM predicted values for each fitness measure over time, up to 20 test occasions. Predicted values are adjusted for age, NDI and gender.

Exercise progression during this intervention program occurs at a rate appropriate for each individual. The initial use of machine-based equipment allows the participant to perform each exercise with a focus on correct form and they can experience immediate success (Behm, Faigenbaum, Falk, & Klentrou, 2008; Heyward, 2010; McIntyre, Chivers, Rose, & Hands, 2014). Improvements in outcomes over time may also be attributed to the design of the tests used and participant's knowledge of their results. In the MSFT, participants are paced by their instructors, and the cadence track provides them with feedback on their progress and final result which may importantly increase motivation for these adolescents (Cairney, Hay, Wade, Faught, & Flouris, 2006).

Once the adolescent feels comfortable and competent on the equipment, they are then able to progress to a greater range of exercises using different equipment taking into account their individual capabilities. They progress at their own pace, with encouragement from their trainer, and experience personal success without the stress of competition, as they are not focused on comparing themselves negatively to others (Marsh & Peart, 1988). Barnett, Dawes, and Wilmut, (2012) and Fitzpatrick and Watkinson (2003) also recognized the importance of a supportive environment, and suggested that a gym setting with an encouraging and positive atmosphere was beneficial, particularly for adolescents with movement difficulties.

There are other elements of the program that could also contribute to these sustainable improvements and ongoing participation. Firstly, the program runs continuously twice per year in each University semester. Participants are able to re-enroll each semester for as long as they wish to return, or until they turn 18 years of age. As a result, on average participants have attended the program for three years, whilst some were involved for up to six years. This may be due to them developing a sense of belonging, familiarity, increased self-determination, enjoyment and even motivation to exercise. A study involving 16 of the AMPitup participants, did measure changes in feelings of happiness before and after each session and over one 13 week program. Clark, Farringdon, and McIntyre, (2015) found significant increases in cumulative happiness among the participants across the program. These changes were attributed by the participants to the relationship with their trainer, the group environment and participation in the exercise program. However, we must consider carefully that future research should incorporate investigating socio-cognitive changes (such as self-efficacy) as this could help to explain the ongoing participation and then any sustained commitment once they graduate from the program. Smits-Engelsman et al. (2018) stated that for all interventions there is a pressing need for examining how effectively learned skills and capacities transfer to daily life and participation in sport and recreation activities. As with most intervention studies, the utilization of a LMC control group for comparison would also strengthen the research design and increase understanding about the true effectiveness of the intervention. However this is challenging as it would be difficult to recruit and retain suitable LMC adolescents as controls over a long period of time.

Finally, the adolescents are given a degree of autonomy in deciding which areas of fitness or specific skills they want to work on and are able to set personal goals each week with their trainer. Recent research has reported increased motor learning benefits in environments where participants can make choices during the task (Lewthwaite, Chiviacowsky, Drews, & Wulf, 2015). Providing a sense of autonomy to the experience has been shown to increase outcomes for various activities, including fundamental motor skills, and also link to personal development (Sanli, Patterson, Bray, & Lee, 2013; Tompsett, Sanders, Taylor, & Cobley, 2017). The evidence supports the benefits of ongoing, long-term participation in personally tailored exercise programs, particularly with groups that may be initially hesitant to engage in exercise, such as adolescents with LMC.

4.1. Strengths and limitations

One of the strengths of the current study is the longitudinal data documenting the improvement and sustainability of fitness and strength outcomes with this population. The LMM analysis employed also permitted adjustment for gender, NDI and age. Due to the program being run through a University, and using student trainers as part of their clinical practicums, a benefit for families and participants is that they can be involved for minimal cost. However, this design may not be applicable to all gym based settings.

There are also several limitations that must be acknowledged. Although height and weight were measured, the small sample size did not permit these additional variables to be included in the LMM analysis, therefore we were not able to account for growth when considering the changes in fitness outcomes for this group. Whilst improvements and changes in fitness over time have been found in this program, generalization of program results to different settings with this population is not possible. The lack of a LMC adolescent control group within the research design also limits our understanding on the extent of the intervention impact, however to our knowledge most studies use a TD rather than an LMC control group. The recruitment and tracking of a LMC control group would be difficult. Future research should consider the addition of a LMC comparison control group and follow up of former participants to investigate if changes and engagement in activity is sustained once adolescents have graduated from the program. Finally, the norms for the MAND were developed in the 1970s, however a number of research teams, particularly in Australia, continue to find the test useful with Australian populations (Caeyenberghs, Tsoupas, Wilson, & Smits-Engelsman, 2009; Chia, Guelfi, & Licari, 2010; Hands et al., 2013).

5. Conclusion

The results add to the limited body of knowledge about effective long-term exercise interventions for adolescents with low motor competence. Cardiorespiratory fitness and strength can be improved and sustained in adolescents with LMC when participating in a long-term exercise program. An individually focused program that offers continued participation and runs for 13 weeks, with 2 sessions per week, has shown improved outcomes with this population over time. Interviews with adolescents may provide greater insight about specific components of the program they feel has most helped improve their fitness and strength, why they continue to participate in the program, and perhaps how this may affect their motivation towards exercise. Since children, adolescents and adults with LMC are at greater risk of poorer physical and socio-emotional health, long term effective interventions are critical to ensure sustainable positive outcomes for this population.

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