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Associations between poor gross and fine motor skills in pre-school and peer victimization concurrently and longitudinally with follow-up in school age – results from a population-based study

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Background. Children with poor motor skills are at increased risk of peer victimization. However, it is unclear whether poor gross and fine motor skills are differently linked to peer victimization among pre-school and schoolchildren.

Aims. To investigate associations between poor gross and fine motor skills measured in pre-school and the associations to peer victimization measured concurrently and in school age.

Sample. Data from the Norwegian Mother, Father and Child Cohort Study (MoBa), and the Medical Birth Registry of Norway were used. Participants with complete questionnaires at 3, 5, and 8 years (n = 23 215) were included.

Methods. A longitudinal design and an autoregressive cross-lagged model were used to investigate if poor gross and fine motor skills at 3 and 5 years predicted peer victimization at 5 and 8 years. Because emotional difficulties are associated with both motor skills and peer victimization, the results were adjusted for emotional difficulties.

Results. Only poor fine motor skills at 3 years had a significant association to peer victimization at 5 years. Poor gross motor skills at 5 years had a stronger association to peer victimization measured concurrently compared to poor fine motor skills, and only poor fine motor skills at 5 years was significantly linked to peer victimization at 8 years. No gender difference was found between these paths.

Conclusions. Teachers and parents should be aware that motor skills predict peer victimization, and that poor gross and fine motor skills have different associations to peer victimization measured at different ages.

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Gross and fine motor skills are both important for children's physical and psychological development. Gross motor skills are actions of the large muscle groups and enable climbing, balance, and playing catch (Escolano-Perez, Herrero-Nivela, & Losada, 2020). Gross motor skills influence children's level of physical activity, which in turn influence physical health (Hamilton & Liu, 2018). Fine motor skills are actions of the small muscle groups, which enable precise movements of the face, hands, and feet (Escolano-Perez et al., 2020). Fine motor skills influence children's ability to perform visual motor integration activities, and are important for fine-tuning of facial expressions, classroom activities, and play (Strooband, de Rosnay, Okely, & Veldman, 2020). Both gross and fine motor skills are associated with language development (Wang, Lekhal, Aarø, Holte, & Schjølberg, 2014) and are important for children's social interaction (Bar-Haim & Bart, 2006).

Research has found that young children with poor motor skills, such as children at risk of developmental coordination disorders (DCDs), are less involved in physical social play and more socially withdrawn compared to children with average motor skills (Bar-Haim & Bart, 2006; Smyth & Anderson, 2000). Similarly, Katagiri et al. (2021) found that pre-school children with poor motor skills show later psychosocial maladjustment and peer problems. Researchers argue that peer problems could increase internalizing problems and maladjustment among these children (Katagiri et al., 2021; Mancini, Rigoli, Roberts, Heritage, & Piek, 2018). Research also indicates that children at 3 years of age and older have a growing ability to assess their own and others' academic and motor competence (Morris & Nemcek, 1982; Stipek & Tannatt, 1984). Many children at risk of DCD may therefore be excluded or withdrawn from social situations because their motor accomplishments are obvious for peers and because they feel inadequate. Importantly, young children who are socially withdrawn, submissive, and less sociable are also more likely to be exposed to peer victimization (Perren & Alsaker, 2006).

The association between motor skills and psychosocial adjustment is also found in older children. Motor skills and physical activity measured among Norwegian children during the first year of schooling predicted social standing in the peer group measured in fourth grade (Ommundsen, Gundersen, & Mjaavatn, 2010). Also, clear associations between motor skills and psychosocial well-being have been found among adolescent girls (Viholainen, Aro, Purtsi, Tolvanen, & Cantell, 2014). Earlier studies indicate that motor skills influence school children's peer relations, self-perception, and status in the group (Mancini et al., 2018; Ommundsen et al., 2010; Piek, Baynam, & Barrett, 2006). This raises the question of whether status, self-perception, and peer relations influence each other in a negative cycle for these children. Veenstra, Lindenberg, Munniksma, and Dijkstra (2010) suggest that bullies generally select victims with low acceptance in the peer group because these children are not likely to be defended by significant others. Children with poor motor skills may therefore be more vulnerable because they have a low status among peers and because they have few significant others to defend them in these situations. Given that bullying and peer victimization have such a profound negative impact on children's well-being (Arseneault, Bowes, & Shakoor, 2010), knowledge about who might be early targets is important.

Few studies have investigated and found associations between poor motor skills, DCD, and peer victimization among schoolchildren and adolescents (Bejerot, Plenty, Humble, & Humble, 2013; Campbell, Missiuna, & Vaillancourt, 2012; Törn et al., 2015). Knowledge about this relationship in younger children is particularly lacking. Whereas some find that poor motor skills measured in pre-school years increase the risk of school bullying (Jansen, Veenstra, Ormel, Verhulst, & Reijneveld, 2011), others have shown that motor

development difficulties already increase the risk of peer victimization at 5 years of age (Øksendal, Brandlistuen, Holte, & Wang, 2019). However, whether the risk of peer victimization mostly apply to children with stable motor difficulties is not clear. Children with persistent difficulties and children who only display poor motor skills at a certain age could show different associations to peer victimization. Because many children do not tell adults about peer victimization, adults need to be proactive in their pursuit for who might be involved (deLara, 2012). More knowledge about vulnerable children, such as children with stable or transient poor motor skills, could therefore give us a window of opportunity to prevent and intervene in these situations.

Only Jansen et al. (2011) have investigated the associations between motor skills and peer victimization at different ages (11 and 13 years of age) and only Törn et al. (2015) have adjusted their results for earlier measures of peer victimization. Previous research has found that several children exposed to peer victimization as pre-schoolers also experience peer victimization as school children and that chronic and stable peer victimization is associated with lower school engagement, lower self-perception, and lower academic achievement (Ladd, Ettekal, & Kochenderfer-Ladd, 2017). It is, therefore, important to identify children who may be at risk of prolonged peer victimization from an early age. Furthermore, research suggests that peer victimization might have a more negative impact on self-worth for children with DCD compared to their typically developing (TD) peers (Piek, Barrett, Allen, Jones, & Louise, 2005). We therefore need more knowledge to establish if children with poor motor skills are vulnerable to peer victimization across time or if the vulnerability among school children mostly reflects earlier exposure to peer victimization.

Gross and fine motor skills may be differently related to children's cognitive and social development. For instance, it has been suggested that gross motor skills may be particularly important for perceived athletic competence, and fine motor skills may be particularly important for perceived academic competence among school children (Piek et al., 2006). Indeed, earlier research has shown that fine motor skills are linked to both school readiness (Grissmer, Grimm, Aiyer, Murrah, & Steele, 2010) and math performance (Luo, Jose, Huntsinger, & Pigott, 2007). On the other hand, gross motor skills are associated with physical activity (Logan, Webster, Getchell, Pfeiffer, & Robinson, 2015), which may be important for youths' social standing (Ommundsen et al., 2010). Still, most studies that investigated the association between motor skills and peer victimization have not investigated the specific associations with gross and fine motor skills. One exception is Bejerot and Humble (2013); they found clear associations for gross motor skills and weak associations for fine motor skills and peer victimization reported retrospectively in a clinical sample of adult psychiatric patients. However, these associations could be different when measured prospectively among young children in a population-based sample.

Research has found that boys are more exposed to peer victimization compared to girls (Oncioiu et al., 2020; Wolke, Woods, Stanford, & Schulz, 2001), and that pre-school girls generally have better motor skills compared to boys (Moser & Reikerås, 2016). Furthermore, athletic competence may be particularly important for social status among boys (Chase & Dummer, 1992; Piek et al., 2006). Thus, leaving young boys with poor gross motor skills is especially vulnerable to develop low self-worth, which could have social and emotional implications (Piek et al., 2006). Boys with poor motor skills could therefore be more negatively affected, which in turn could increase the risk of peer victimization. However, Törn et al. (2015) found that the association between motor control and peer

victimization was stronger for adolescent girls. More knowledge is, therefore, needed to understand gender differences between poor motor skills and peer victimization.

Several studies have found that poor motor skills co-occur with symptoms of anxiety and depression (Omer, Jijon, & Leonard, 2019; Schoemaker & Kalverboer, 1994; Sigurdsson, van Os, & Fombonne, 2002; Waszczuk, Leonard, Hill, Rowe, & Gregory, 2016). Earlier studies have also found that peer victimization and emotional difficulties are associated (Perren, von Wyl, Stadelmann, Burgin, & von Klitzing, 2006; Reijntjes, Kamphuis, Prinzie, & Telch, 2010; Wichstrøm, Belsky, & Berg-Nielsen, 2013). In addition, peer victimization could facilitate the association between poor motor skills and emotional difficulties (Campbell et al., 2012; Lingam et al., 2012). Altogether, these findings indicate that emotional difficulties are linked with both peer victimization and motor skills. The association between poor motor skills and peer victimization could therefore be explained by co-occurring emotional difficulties. Disentangling these associations provides a better understanding of how motor skills are linked to peer victimization.

Bullying is defined as repeated aggression (two to three times a month) where there is an imbalance of power between the perpetrator(s) and the child exposed to bullying, and the behaviour is intended to harm (Solberg & Olweus, 2003). Due to cognitive and social immaturity, an imbalance of power and intention to harm may be difficult to measure among young children (Vlachou, Andreou, Botsoglou, & Didaskalou, 2011). Peer victimization is a form of peer abuse in which a child is regularly the target of aggression; however, all aspects of the bullying definition may not necessarily apply (Kochenderfer & Ladd, 1996). The broader term *peer victimization* was therefore used in our study.

The aim of this study was to investigate if poor gross and fine motor skills at 3 and 5 years were followed by increased peer victimization at 5 and 8 years when adjusted for emotional difficulties at 3, 5, and 8 years. By using a cross-lagged panel model, we adjusted for both earlier and concurrent measures of motor skills and peer victimization, and therefore investigated the specific associations between these measures across time. More specifically, we addressed the following hypotheses:

1. Poor gross and fine motor skills measured at 3 and 5 years predict peer victimization at 5 years.
2. Poor gross and fine motor skills measured at 3 and 5 years predict peer victimization at 8 years.
3. These associations will be different for boys and girls.

Methods

Participants

We used data from the Norwegian Mother, Father and Child Cohort Study (MoBa). MoBa is a population-based pregnancy study conducted by the Norwegian Institute of Public Health. Participants were recruited from all over Norway from 1999 to 2008. The women consented to participation in 41% of the pregnancies. The cohort now includes 114, 500 children, 95, 200 mothers and 75, 200 fathers (Magnus et al., 2016). Information on health, lifestyle, and child development was collected using questionnaires during pregnancy and after birth. For this study, 23, 215 children with complete mother-rated questionnaires at 3, 5, and 8 years of age were included. The mothers had a mean age of 31 years when giving birth (ranging from 17 to 47 years). The mean gestational age of the child was

40 weeks at birth (ranging from 24 to 44 weeks). Most mothers had higher education corresponding to four years at university/college when enrolled in the study (ranging from junior high school to four years or more of higher education).

We used the 10th quality assured version of the dataset released in 2017. The establishment of MoBa and initial data collection were based on a license from the Norwegian Data Protection Authority and approval from the Regional Committees for Medical and Health Research Ethics. The MoBa cohort is based on regulations from the Norwegian Health Registry Act. The Norwegian Data Protection Authority has approved this study.

Measurements

To account for measurement error, latent variables were used to measure poor motor skills at 5 years. Confirmatory factor analysis was used to develop measurement models for the latent variables, and the comparative fit index (CFI), the Tucker–Lewis index (TLI), and the root mean square error of approximation (RMSEA) were used as fit indices. Motor skills were assessed with selected items for MoBa from validated measurement scales. All items included and results from measurement models are presented in the Appendix S1. All measurement models show adequate model fit. Motor skills were treated as continuous variables with categorical indicators. According to Gadermann, Guhn, and Zumbo (2012), Cronbach's alpha could underestimate the reliability of a scale if it is measured with ordinal variables. Ordinal alphas based on the polychoric correlation matrix were therefore used to estimate measurement reliability in this study (Gadermann et al., 2012).

Motor skills at 3 years were measured with two items on gross motor skills and two items on fine motor skills from the Ages and Stages Questionnaires (ASQ; Squires, Bricker, & Potter, 1997). Items assessing motor skills included questions such as 'Can your child catch a large ball with both hands'? and 'Can your child undo one or more buttons'? Response categories were 'yes', 'sometimes' or 'not yet'. ASQ report favourable validity measured in a Norwegian sample (Richter & Janson, 2007). The polychoric correlation was .52 for gross motor skills and .39 for fine motor skills.

Motor skills at 5 years were measured with five items on gross motor skills and five items on fine motor skills from the Child Development Inventory (CDI; Ireton, Thwing, & Currier, 1977). Items assessing motor skills included statements such as 'Rides a two-wheeled bike, with or without training wheels' and 'Colors within the lines in a coloring book'. Response categories were 'yes' or 'no'. CDI provides a useful measure of children's motor development (Ireton & Glascoe, 1995). The polychoric reliability was .80 for gross motor skills and .88 for fine motor skills.

Peer victimization at 5 years was measured using the mothers' ratings of the statement 'My child is teased/bullied by other children' in the past 2 months. Response categories were 'never', 'sometimes' or 'often'. Peer victimization at 8 years was measured using the mothers' responses to the question 'In the past 12 months, has your child been teased/bullied by other children'? Response categories were 'never', 'seldom', 'two/three times a month', 'once a week' or 'many times a week'. The measure of peer victimization at 8 years is similar to a student-rated question where bullying behaviour is assessed annually for Norwegian school children (5th grade and older) and has shown good construct validity (Solberg & Olweus, 2003; Wendelborg, 2020).

Emotional difficulties were included as control variables. The children's sex was retrieved from the Medical Birth Registry of Norway, which is a national health registry containing information about all births in Norway (Irgens, 2000).

Statistical analysis

First, the unadjusted bivariate correlations between all variables were investigated (Table 1). After developing measurement models, the relationships among poor gross and fine motor skills and peer victimization were investigated in a cross-lagged autoregressive panel model. The stability of poor gross and fine motor skills and peer victimization was accounted for by estimating the autoregression between each point of measurement.

Then, all direct paths between motor skills and peer victimization were investigated. Wald tests comparing the paths between poor gross and fine motor skills and peer victimization were performed. Because emotional difficulties are associated with both motor skills and peer victimization, all results were adjusted for emotional difficulties at 3, 5, and 8 years. To account for confounding due to age differences between children at the time of filling out the questionnaires, results were adjusted for the children's ages at 3, 5, and 8 years.

We also investigated nested models grouped by gender. As a default, measurement models for boys and girls were set to be equal, and the paths were compared. Because most children accomplish age-adopted motor tasks, our variables are highly skewed. The weighted least squares mean and variance (WLSMV) estimator was used in our study because this is the best option for modelling categorical or ordered data (Muthén & Muthén, 2017). CFI, TLI, and RMSEA were used as model fit indicators. Analyses were performed in Mplus version 8.0 (Muthén & Muthén, 2017).

Results

Unadjusted polychoric correlations

Unadjusted bivariate polychoric correlations between poor gross and fine motor skills at 3 and 5 years, peer victimization at 5 and 8 years, emotional difficulties at 3, 5, and 8 years, and the children's gender are shown in Table 1.

Structural equation modelling

Figure 1 shows the paths from the autoregressive cross-lagged model illustrating associations between poor gross and fine motor skills at 3 and 5 years and peer victimization at 5 and 8 years. Paths in our model are controlled for the stability from earlier measures for each variable, and the influence of associated variables. For instance, poor fine motor skills at 5 years predicted peer victimization at 8 years (adjusted for peer victimization at 5 years, poor fine motor skills at 3 years, and poor gross motor skills at 3 and 5 years), indicating the specific link between poor fine motor skills at 5 years and a change of peer victimization from 5 to 8 years.

Table 2 shows the coefficient estimates from the autoregressive cross-lagged model. First, our results show high stability of both poor gross and fine motor skills and peer victimization. We found high correlations between poor gross and fine motor skills, and found that poor fine motor skills at 3 years was associated with poor gross motor skills at 5 years. We also found that only poor fine motor skills at 3 years had a significant association with peer victimization at 5 years. Further, only poor fine motor skills at 5 years had a significant association with peer victimization at 8 years. Results from the Wald test show that poor gross motor skills had a stronger correlation with peer victimization compared to poor fine motor skills when measured at 5 years. No gender

Table 1. Unadjusted correlations between poor gross and fine motor skills, peer victimization, emotional difficulties, and gender at 3, 5, and 8 years

	Poor gross motor skills (3 years)	Poor fine motor skills (3 years)	Poor gross motor skills (5 years)	Poor fine motor skills (5 years)	Emotional difficulties (3 years)	Emotional difficulties (5 years)	Emotional difficulties (8 years)	Peer victimization (5 years)	Peer victimization (8 years)	Gender (1 = boy, 2 = girl)
Poor gross motor skills (3 years)	1	.691 ($p < .001$)	.736 ($p < .001$)	.431 ($p < .001$)	.266 ($p < .001$)	.160 ($p < .001$)	.155 ($p < .001$)	.107 ($p = .001$)	.062 ($p < .001$)	−.075 ($p < .001$)
Poor fine motor skills (3 years)		1	.546 ($p < .001$)	.568 ($p < .001$)	.171 ($p < .001$)	.130 ($p < .001$)	.093 ($p < .001$)	.148 ($p < .001$)	.070 ($p < .001$)	−.585 ($p < .001$)
Poor gross motor skills (5 years)			1	.603 ($p < .001$)	.238 ($p < .001$)	.267 ($p < .001$)	.184 ($p < .001$)	.273 ($p < .001$)	.111 ($p < .001$)	−.292 ($p < .001$)
Poor fine motor skills (5 years)				1	.146 ($p < .001$)	.160 ($p < .001$)	.166 ($p < .001$)	.228 ($p < .001$)	.145 ($p < .001$)	−.552 ($p < .001$)
Emotional difficulties (3 years)					1	.702 ($p < .001$)	.384 ($p < .001$)	.293 ($p < .001$)	.131 ($p < .001$)	.026 ($p = .001$)
Emotional difficulties (5 years)						1	.479 ($p < .001$)	.459 ($p < .001$)	.177 ($p < .001$)	.034 ($p < .001$)
Emotional difficulties (8 years)							1	.347 ($p < .001$)	.499 ($p < .001$)	.031 ($p < .001$)
Peer victimization (5 years)								1	.375 ($p < .001$)	−.147 ($p < .001$)
Peer victimization (8 years)									1	−.078 ($p < .001$)
Gender (1 = boy, 2 = girl)										1

Note. Poor gross and fine motor skills at 5 years, and emotional difficulties at 3, 5, and 8 years are latent variables. Poor gross and fine motor skills at 3 years, peer victimization, and gender are observed variables.

difference was found between the paths in our model. CFI was .956, TLI was .951, and RMSEA was .019 for the full model. This indicates good model fit.

Discussion

Consistent with the current literature, our results show that children with poor motor skills are more exposed to peer victimization compared to their TD peers (Bejerot et al., 2013; Campbell et al., 2012; Jansen et al., 2011; Øksendal et al., 2019; Törn et al., 2015). However, as shown in Figure 1 and Table 2, we found that only poor fine motor skills predicted peer victimization over time, whereas at 5 years, the concurrent association with peer victimization was strongest for poor gross motor skills. Our findings therefore expand current knowledge by highlighting the age-specific influence of poor gross and fine motor skills on peer victimization.

The most interesting finding was that poor fine motor skills measured at 5 years predicted change in peer victimization from 5 to 8 years, whereas poor gross motor skills did not. Because few studies have investigated the link between fine motor skills and peer victimization, we can only hypothesize about reasons for this association. Piek et al. (2006) investigated the difference between gross and fine motor skills and self-perception in school children and adolescents. They found that poor fine motor skills were associated with lower perceived scholastic ability (Piek et al., 2006). Accordingly, research has found associations between fine motor skills and children's math and reading accomplishments (Luo et al., 2007; Son & Meisels, 2006), which could be explained by visual spatial integration, such as the ability to synchronize hand–eye movements (Carlson, Rowe, & Curby, 2013). Similarly, Grissmer et al. (2010) found that fine motor skills had a clear association with school readiness, including math performance and reading ability. Interestingly, the same association was not found for gross motor skills (Grissmer et al., 2010). Finally, Kim, Carlson, Curby, and Winsler (2016) found that fine motor skills measured among pre-school children with developmental disorders predicted cognitive and social skills.

Altogether, these findings indicate that fine motor skills are linked to both social skills and academic performance – which in turn could influence social standing in the group. Indeed, research indicates that academic performance is linked to social competence, peer acceptance, and subjective well-being (Chen, Rubin, & Li, 1997; Yang, Tian, Huebner, & Zhu, 2019). In addition, Metsäpelto, Zimmermann, Pakarinen, Poikkeus, and Lerkkanen (2020) found that math grades were associated with children's self-esteem, which also predicted emotional difficulties. Furthermore, researchers argue that children with low acceptance and low status among peers are more vulnerable to peer victimization (Veenstra et al., 2010). The association between poor fine motor skills and peer victimization could therefore be indirectly linked through poor academic performance, poor social skills, and low status among peers. Still, more research is needed to understand mechanisms behind this association.

Considering the importance of sports achievements and gross motor performance as a social determinant among school children (Chase & Dummer, 1992; Ommundsen et al., 2010) and earlier findings showing associations between talents in physical education and school bullying (Bejerot et al., 2013), it is surprising that poor gross motor skills had such a small impact on peer victimization measured in school. However, it has been suggested that school children are increasingly involved in leisure time and school activities, which include fine motor skills such as gaming, computer skills, and social media (Vedul-Kjelsås,

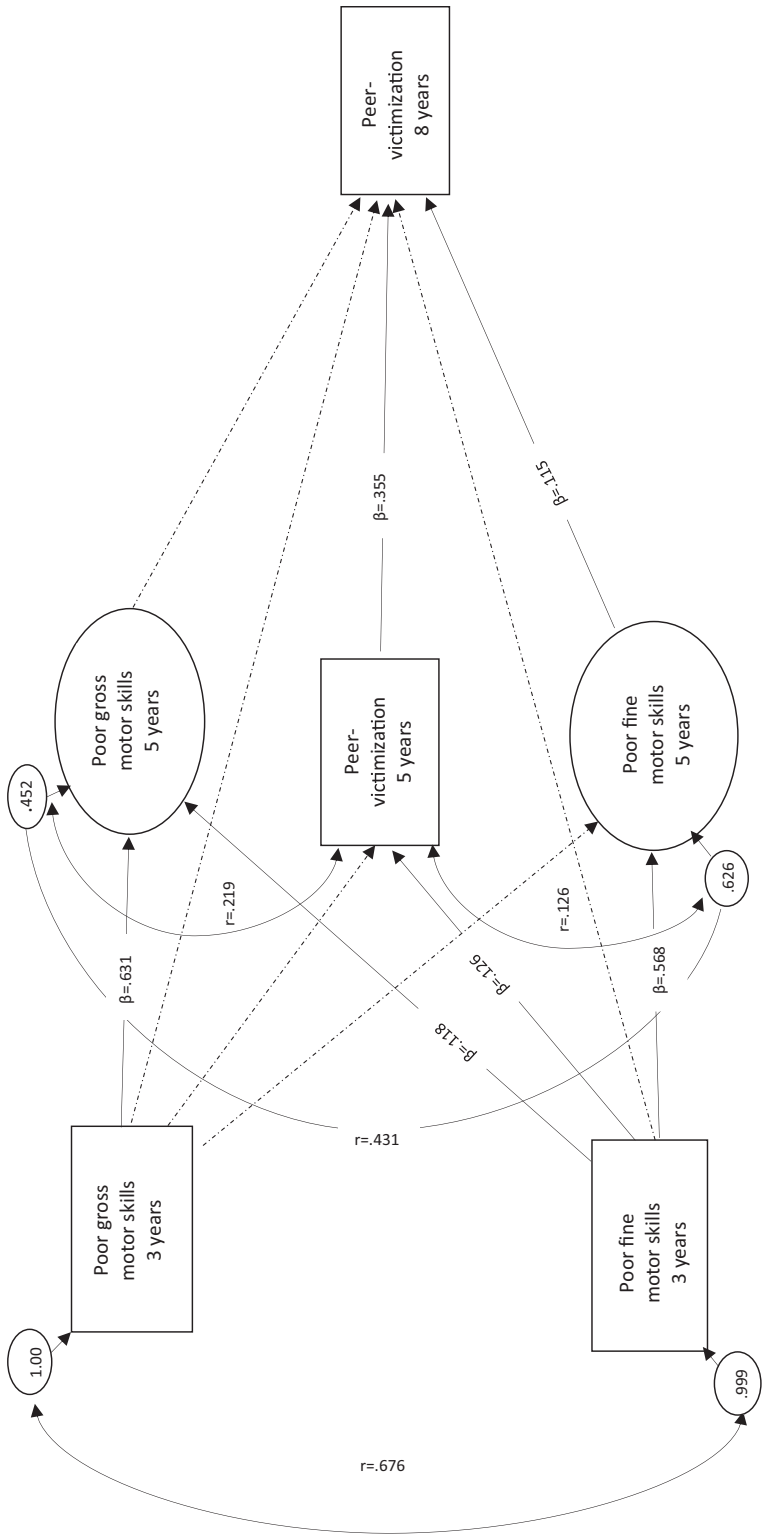

Figure 1. Structural equation model of poor gross and fine motor skills at 3 and 5 years and peer victimization at 5 and 8 years. Model shows significant paths between estimates. Dotted lines show non-significant paths. Poor gross and fine motor skills at 5 years are latent variables, poor gross and fine motor skills at 3 years and peer victimization are observed variables. The root mean square error of approximation was .019, comparative fit index was .956 and Tucker-Lewis index was .951. Standardized results adjusted for emotional difficulties and the child's age at 3, 5 and 8 years.

Table 2. Auto-regressive effects, correlations, cross-lagged effects, and structural effects of poor gross and fine motor skills (measured at 3 and 5 years) and peer victimization (measured at 5 and 8 years), adjusted for emotional difficulties and the child's age at 3, 5, and 8 years

	Standardized coefficients	95% CI	SE	*p*-value
Auto-regressive paths				
GM 3 years–GM 5 years	.631	(0.537, 0.724)	.048	<.001
FM 3 years–FM 5 years	.568	(0.507, 0.628)	.031	<.001
PV 5 years–PV 8 years	.355	(0.315, 0.394)	.020	<.001
Correlations				
GM 5 years–PV 5 years	.219	(0.141, 0.297)	.040	<.001
FM 5 years–PV 5 years	.126	(0.074, 0.178)	.026	<.001
GM 3 years–FM 3 years	.676	(0.632, 0.721)	.023	<.001
GM 5 years–FM 5 years	.431	(0.377, 0.485)	.028	<.001
Cross-lagged paths				
GM 3 years–FM 5 years	.003	(−0.070, 0.076)	.037	=.943
FM 3 years–GM 5 years	.118	(0.031, 0.204)	.044	=.008
Structural paths				
GM 3 years–PV 5 years	−.021	(−0.141, 0.100)	.062	=.739
FM 3 years–PV 5 years	.126	(0.026, 0.226)	.051	=.014
GM 5 years–PV 8 years	−.052	(−0.133, 0.029)	.041	=.209
FM 5 years–PV 8 years	.115	(0.064, 0.165)	.026	<.001
GM 3 years–PV 8 years	.039	(−0.067, 0.145)	.054	=.470
FM 3 years–PV 8 years	−.056	(−0.127, 0.016)	.036	=.128

Note. GM = poor gross motor skills; FM = poor fine motor skills; PV = peer victimization; CI = confidence interval; and SE = standard error.

Stensdotter, & Sigmundsson, 2013). It is, therefore, possible that gross motor skills are becoming a less important determinant of schoolchildren's peer acceptance and therefore have a lesser impact on peer victimization.

Conversely, when measured concurrently at 5 years, our results show that both poor gross and fine motor skills are linked to peer victimization, with a stronger association for poor gross motor skills. Like fine motor skills, studies have found associations between gross motor skills and social skills (Leonard & Hill, 2014; Pusponegoro et al., 2016). In addition, Piek et al. (2006) found that gross motor abilities influence perceived athletic competence – which, in turn, was associated with feelings of self-worth. Schoemaker and Kalverboer (1994) found that clumsy children, measured from 6 through 9 years, were more introvert, judged themselves to be less competent regarding physical and social skills and had more signs of anxiety both in general and when performing movement tasks. Furthermore, clumsy children had fewer friends and were less often invited to join others in play (Schoemaker & Kalverboer, 1994). Children with poor gross motor skills may therefore appear awkward and withdrawn in social settings that demand physical activity and physical play.

Interestingly, Cairney et al. (2005) found a link between DCD, generalized self-efficacy, and physical activity. The researchers argue that low self-efficacy could be one factor that explains why children with DCD show low athletic participation (Cairney et al., 2005). In addition, it has been suggested that children with low perceived social self-efficacy use less mature and effective ways of coping with loneliness (Andreou, Didaskalou, &

Vlachou, 2015). Furthermore, children who reported being victims of bullying also reported more self-blame and lower self-worth (Graham & Juvonen, 1998). Children with poor motor skills could therefore get caught up in a negative spiral of low self-efficacy, negative peer interactions, and peer victimization.

Importantly, the associations between poor gross and fine motor skills at 5 years and peer victimization were adjusted for poor gross and fine motor skills at 3 years (illustrated in Figure 1). This suggests that the association with peer victimization applies not only to children with stable poor motor skills but also to all children who display poor motor skills at 5 years, irrespective of their difficulties at 3 years. Our results therefore indicate that children with transient and mild difficulties are also vulnerable. Interestingly, Schoemaker and Kalverboer (1994) found that moderately clumsy children displayed more social negative behaviour compared to severely clumsy children. Accordingly, a recent study found that children with mild and transient difficulties experienced more peer victimization compared to children with no difficulties (Øksendal et al., 2021). However, mild clumsiness may be difficult for adults to detect (Smyth, 1992). Without support and intervention from adults, children with transient or mild clumsiness may be involved in persistent negative social behaviour, which could develop into peer rejection and peer victimization.

Another interesting finding was that also from 3 to 5 years, the association between motor skills and later peer victimization was only significant for poor fine motor skills. It has been suggested that children at 3 years and older show an increasing ability to assess their own and others' academic and motor competence (Morris & Nemcek, 1982; Stipek & Tannatt, 1984) and that social non-physical play decreases as children grow older (Smyth & Anderson, 2000). Hence, 3-year-old children may be too young to consider their own or their peers' motor accomplishments, and they may be too young to participate in play activities that demand advanced gross motor skills, such as bicycling, climbing, or playing catch. Therefore, gross motor impairments may not be as apparent or as important when interacting with peers. In a previous study, it was found that fine motor skills and executive functioning among 3- to 5-year-old children correlated, and that they both predicted kindergarten achievements (Cameron et al., 2012). Given that low executive functioning, such as inhibition problems, may be a risk factor for peer victimization (Verlinden et al., 2014), it is possible that executive functioning could explain the association between poor fine motor skills and peer victimization.

Our results show a moderate stability of peer victimization from 5 to 8 years and, therefore, resemble research showing that many children exposed to peer victimization as pre-schoolers are also exposed to peer victimization in school (Ladd et al., 2017). Accordingly, the structural paths shown in Figure 1 illustrate that although poor gross and fine motor skills at 3 years showed no direct link to peer victimization at 8 years, paths going through poor gross and fine motor skills and peer victimization at 5 years were found. Our results, therefore, indicate that the stability of motor skills and prior exposure to peer victimization predict peer victimization at school age for children with poor gross and fine motor skills measured at 3 years.

Verkuyten and Thijs (2002) argue that school satisfaction is an important aspect of children's quality of life. School satisfaction is linked to factors such as having meaningful relationships with peers and perceiving oneself as a competent learner (Baker, Dilly, Aupperlee, & Patil, 2003). The results from this study, compared with those in previous research, indicate that motor skills influence peer interactions and children's academic and athletic competence. Motor skills may therefore influence school satisfaction.

Research has found positive effects for intervention programmes aimed at increasing motor skills for young children (Logan, Robinson, Wilson, & Lucas, 2012; Strooband et al., 2020). For instance, Hamilton and Liu (2018) found that pre-school children from a low socioeconomic background benefited from interventions that stimulated gross and fine motor skills. However, although the importance of motor development is acknowledged by researchers, practitioners, and educators, the development and inclusion of gross and fine motor intervention in ECEC policy are still lacking emphasis (Hamilton & Liu, 2018; Moser & Reikerås, 2016).

Among school children, research implies that interventions, which include extended physical education and motor skills training, improve motor skills and academic performance (Ericsson, 2008; Ericsson & Karlsson, 2014). Interestingly, children with the lowest motor skills had the best effect of the intervention (Ericsson, 2008). Ericsson (2008) argues that mapping and stimulating children's motor skills should be performed from an early age, and that physical educational should be available as special education. Future research should investigate if interventions aimed at stimulating motor skills also influence social development and peer relations.

Strengths and limitations

We have used a large population-based sample and an autoregressive cross-lagged model to investigate paths between poor gross and fine motor skills and peer victimization. Our study is among the first to investigate and find that poor motor skills predict peer victimization after adjusting for emotional difficulties, thus expanding current knowledge by indicating that the association between poor motor skills and peer victimization cannot be explained by emotional difficulties. Latent variables were used to measure gross and fine motor skills – except for the separate measures of gross and fine motor skills at 3 years, where only two items were included in each construct. By using latent variables, our measures were accounted for bias owing to construct irrelevant variance, which could make our model more robust (Tomarken & Waller, 2005).

However, when using the cross-lagged model, it is not possible to separate the within-person stability from the between-person stability (Hamaker, Kuiper, & Grasman, 2015). The stability of our measurements could, therefore, reflect related variables such as stable child characteristics. In addition, RMSEA, TLI, and CFI may be less useful in discovering model-data misfit when ordinal or categorical data are used in structural equation modelling, but alternative model fit parameters have not been agreed on (Xia & Yang, 2019).

According to conventional interpretations of effect size, many of the estimates shown in Table 2 are small. However, the magnitude of effect size between earlier predictors and later outcomes in longitudinal studies can be greatly reduced when controlling for measurement stability (Adachi & Willoughby, 2015). Practical and scientific reasoning should determine if the effect size in question is relevant and useful (McCartney & Rosenthal, 2000). The harmful effects of peer victimization have been demonstrated in many studies (Arseneault et al., 2010; Sigurdson, Undheim, Wallander, Lydersen, & Sund, 2018; Wolke, Copeland, Angold, & Costello, 2013). Our results indicate that vulnerable traits already emerge at 3 years. This reveals information about who might be early targets of peer victimization.

Potential self-selection bias in MoBa is a concern and has been investigated. Mothers in MoBa on average have better health and socioeconomic status compared to Norwegian mothers (Nilsen et al., 2009), suggesting that self-selection bias could influence exposure–

outcome estimates (Biele et al., 2019). This should be considered when interpreting our results.

An important concern is that peer victimization at 5 and 8 years was only assessed with one item. Additional measures of peer victimization could give us important knowledge about the variation in these experiences. Unfortunately, this was not available. In addition, motor skills and peer victimization were measured somewhat differently at different ages and could therefore reflect different constructs. However, our results show high stability across time, thus indicating that we are measuring the same constructs. Furthermore, one could argue that using different measures across time simply reflects different developmental stages for children. For instance, using similar items to measure motor skills at 3 and 5 years may be inappropriate because children's motor accomplishments are so different at these ages. Similarly, the understanding of peer victimization among young children may not include the same nuances as for school children (Vlachou et al., 2011). Therefore, broader categories to measure peer victimization among younger children, as is done in this study, may be more appropriate.

Finally, stable characteristics belonging to the mother could influence our estimates. Accordingly, our results may be biased because mothers are assessing both motor skills and peer victimization.

Conclusions

Our results indicate that poor gross and fine motor skills predict peer victimization. The findings expand current knowledge by underlining the age-specific influence of poor gross and fine motor skills on peer victimization. Given that gross and fine motor skills may be differently linked to academic and athletic competence, our findings shed light on possible underlying mechanisms explaining why these children are targeted in pre-school and school age. Motor skills are overt and relatively easy to detect. Parents and teachers should be aware that children struggling with age-appropriate motor accomplishments may also be at risk of experiencing peer victimization. Finally, our results highlight the importance of implementing interventions against peer victimization already in pre-school years.

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Conflict of interest

The authors declare no conflict of interest.

Author contributions

Arne Holte (Conceptualization; Methodology; Supervision; Validation; Writing – review & editing) Mari Vaage Wang (Conceptualization; Formal analysis; Methodology; Project administration; Supervision; Validation; Writing – review & editing) Elise Øksendal (Conceptualization; Formal analysis; Funding acquisition; Methodology; Project administration; Validation; Writing – original draft; Writing – review & editing) Ragnhild Eek

Brandlistuen (Conceptualization; Formal analysis; Methodology; Supervision; Writing – review & editing).

Data availability statement

The consent given by the participants does not open for storage of data on an individual level in repositories or journals. Researchers who want access to data sets for replication should submit an application to datatilgang@fhi.no. Access to data sets requires approval from the Regional committees for medical and health research ethics in Norway and a formal contract with MoBa.

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Supporting Information

The following supporting information may be found in the online edition of the article:

Appendix S1 Selected items and results from measurement models assessing motor skills and emotional difficulties.