

# Network Effects on Adolescents' Perceived Barriers to Physical Activity

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**Background:** Adolescent physical activity (PA) is widely linked to positive health outcomes. Unfortunately, 80% of adolescents do not meet recommendations, which may be due to perceived barriers to PA. Peer interactions significantly affect adolescent PA behaviors. This study aims to analyze distribution of PA barriers throughout adolescent friendship networks and barriers' associations with PA. **Methods:** Adolescents ( $N = 383$ , mean = 10.77 y,  $SD = 1.30$  y, 51.4% male) reported frequency of experiencing PA barriers (body related, social, fitness, convenience, and resource) and names of their friends. Average steps and minutes of moderate- to vigorous-intensity PA per day were measured using accelerometers. Linear network autocorrelation models determined if friends perceived barriers similarly when compared with nonfriends and analyzed relationships between barriers and objective PA measures while controlling for network effects. **Results:** Moderate- to vigorous-intensity PA, steps per day, body-related barriers, and social barriers displayed significant network effects, suggesting significant association with the scores of their friends. Average steps per day were significantly associated with age, sex, and social barriers, while inversely associated with fitness barriers. **Conclusions:** This research suggests adolescents' perceived PA barriers are significantly associated with those of their friends. Researchers and practitioners aiming to reduce barriers to PA among adolescents may wish to assess peer reinforcing effects.

**Keywords:** accelerometry, behavioral science, health behavior, social network analysis, friends

Physical activity (PA) has been linked to many positive health outcomes (eg, disease prevention, improved mental health) and is critical in physical and social development throughout childhood and adolescence.<sup>1</sup> The World Health Organization recommends adolescents attain at least 60 minutes of moderate to vigorous PA (MVPA) each day<sup>2</sup>; however, 80% of adolescents worldwide do not meet these recommendations.<sup>3</sup> Data also show a marked decline in MVPA levels throughout childhood and well into adolescence, as well as a significant disparity between sex as female children and adolescents are less active than their male counterparts at every age group.<sup>4</sup> Due to this decline, it is imperative for health researchers to understand what may be preventing adolescents from participating in PA.

Previous research suggests personal, social, and environmental barriers play a role in reduced amounts of PA during adolescence.<sup>5,6</sup> Perceived barriers to PA can come in many forms and have typically been classified into psychological (eg, lack of skill or self-efficacy), sociocultural (eg, lack of support or sedentary norms), and environmental (eg, weather or access to resources/equipment) domains.<sup>7</sup> Furthermore, time constraints, lack of social support (parental and/or peer), motivational levels, perceived competence, and body image were all specifically mentioned as primary barriers to PA among adolescents in a review of qualitative studies.<sup>8</sup> The specific type and number of barriers perceived may also vary depending on sex, race, ethnicity, activity level, weight status, birth order, and time of the year.<sup>8–11</sup> For example, Zabinski et al<sup>11</sup> found overweight adolescents perceive barriers more frequently than their normal-weight counterparts. Despite the

variation in barriers perceived, in general, barriers are consistently linked to lower amounts of PA among adolescents.<sup>5,6,9</sup>

In addition to perceived barriers, adolescents' PA behaviors are impacted by their friends' behaviors.<sup>12</sup> Social support<sup>13</sup> and co-participation in PA<sup>14</sup> have been positively associated with PA engagement among adolescents. Furthermore, adolescents tend to cluster (ie, create dense friend groups) based on PA, as well as emulate the PA behaviors of their friends.<sup>15</sup> While adolescents can develop similar PA behaviors as their peers when emerged in the same environment/context (eg, physical education at school, a dance class<sup>16</sup>), adolescents often exude similar PA behaviors based on their network connections, either through selecting friends similar to them (ie, Child A plays soccer, and becomes friends with Child B who also plays soccer), and/or becoming more like them overtime (ie, the more time Child A spend with Child B, the more Child A engages in similar activity as Child B) in either amount or type of activity.<sup>12</sup>

One way to investigate the impact of friendship on health behaviors such as PA is by using social network analysis (SNA). The SNA is a set of theories and methodologies, which allow researchers to examine social structures and influences by detailing the social connections within a group.<sup>17</sup> While SNA is itself a combination of sociological and mathematic graph theories,<sup>17</sup> it can also help examine social and community contexts within the social determinants of health as well as the interpersonal level of the socio ecological model.<sup>18,19</sup> At its core, social network theory posits that the way people are connected to one another is just as important if not more important than certain attributes or characteristics of the individual.<sup>17</sup> Sociocentric or whole network analysis is a commonly used SNA approach in which a researcher aims to uncover all of the social connections within a specific group.<sup>20</sup> In this way, researchers can determine significant factors related to social connection and how specific attributes (eg, PA or perceived barriers) are distributed throughout the network.<sup>20</sup>

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## Study Aims

Atkin et al.<sup>21</sup> called for innovative approaches to understand the effect perceived barriers may have on adolescent PA specifically within interpersonal, social, and behavioral contexts. In response, this article aims to use SNA to investigate how social connections within schools may influence adolescents' PA and perceived barriers to engaging in PA. In line with Atkin et al.,<sup>21</sup> this article also aims to investigate interpersonal effects on perceived barriers by assessing the similarity between friends. Based on the observed similarity in adolescents' PA<sup>12</sup> and the negative correlation between perceived barriers and PA in adolescents<sup>22</sup> the authors hypothesized that:

H1: Adolescents' PA is more similar to that of their friends, compared with nonfriends.

H2: Adolescents' PA is negatively associated with perceived barriers to PA.

H3: Adolescents' perceived barriers to PA are more similar to the perceived barriers of friends, compared with nonfriends.

## Methods

### Study Design

This study used data previously collected from the *MyMovez* project,<sup>23</sup> which investigated adolescent health behaviors within social networks. The original project received approval from the Radboud University Institutional Review Board prior to the start of the study. The project consists of a cross-sequential design, with a primary school and a secondary school cohort. While data were collected at 3 separate time points, this study used data from the third wave of data collection (between June and July 2016) as this was the sole time point in which the selected measures (ie, perceived barriers to PA) were assessed.

A sociocentric SNA design (ie, whole network design) was employed in this project. Research suggests at least 60% of a given group (eg, classroom) must participate in data collection in order for a sample to be representative of the entire network.<sup>24</sup> Classrooms were only used in analysis if this 60% threshold was achieved. A total of 444 adolescents were recruited from 25 classrooms (17 primary and 8 secondary) within 12 schools. These 25 classrooms served as the 25 networks in our study. Out of the 444 participants, 383 (86.3%) had complete data (participated in SNA, perceived barriers scale, and accelerometer evaluation) to be analyzed further.

Prior to the beginning of the project, parents or legal guardians of the adolescents in the invited classrooms were informed about the project and were asked to provide consent via paper and pencil or online via the project website. Participants also signed assent forms prior to participation. On the first day of data collection, instructions were given, and participants received the *MyMovez* Wearable Lab: a smartphone with a custom-made research application and a wrist-worn accelerometer. Participants were instructed that the accelerometer was water resistant so it could be worn at all times. The accompanying research smartphone was equipped with a research application where participants completed daily questionnaires (eg, peer questions and perceived barriers to PA questionnaire).

## Measures

**Perceived Barriers to PA.** Perceived barriers to PA were measured using a 21-item questionnaire.<sup>11</sup> Adolescents were asked to rate each item based on the frequency it kept them from being active on a Likert scale, ranging from never (1) to always (6). The original 21-item scale was created with 5 subscales or categories of perceived barriers: body related ( $n = 3$ ;  $\alpha = .86$ ; eg, "I am self-conscious about my looks when I do activities"), convenience ( $n = 3$ ;  $\alpha = .72$ ; eg, "I have homework"), resource ( $n = 5$ ;  $\alpha = .80$ ; eg, "I do not have a convenient place to do PA"), social ( $n = 5$ ;  $\alpha = .83$ ; eg, "I do not have anyone at my skill level to do PA with"), and fitness ( $n = 5$ ;  $\alpha = .88$ ; eg, "PA is too much work"). When measured for reliability, internal consistency for the entire scale was excellent in this sample ( $\alpha = .93$ ); each subscale also exhibited good to excellent consistency.

**Objectively Measured PA.** A wrist-worn accelerometer (Fitbit Flex®, San Francisco, CA) was used to measure the number of steps and minutes of MVPA per day for 7 days.<sup>25</sup> Fitbit Flex® devices show strong test-retest reliability and moderate validity when compared with ActiGraph monitors.<sup>25,26</sup> Incomplete days (<1000 steps or <1440 min [24 h]) of measurement were excluded from the analyses. When participants had less than 3 days of observed data, but at least 1 day of data, single multilevel (predictive mean matching) imputation<sup>27</sup> was used to generate imputed PA data (based on 500 iterations). The data points were imputed based on other PA data of the participant, classroom, school, day of the week, sex, age, body mass index, weather conditions of that day, and psychosocial measures of the participant (ie, athletic competence, attitude, enjoyment, intentions, motivation, and subjective norms). Roughly 23.5% of data points were imputed; imputed values were not significantly different than observed data. Imputation methods have been described at length in other work.<sup>23</sup>

**Sociocentric Data.** Participants were asked one time to nominate or indicate who their friends were through the smartphone app on a random moment on the first day of the study. The application provided a list with the names of all students in the same classroom or grade. Participants were able to nominate anyone on the provided list that they considered friends. In addition, a search field was provided so that participants could search for the names of classmates. Participants were required to nominate at least one peer from the same grade and self-nominations were not possible. Nominations outside of the same classroom were excluded from this study. Additional information pertaining to the network data collection process is available in previously published articles from this study.<sup>23</sup> Each nomination resulted in an edge going from the nominee (ego) to the nominated (alter), resulting in a directed network. These edges were not weighted in the case of multiple redundant nominations. In other words, network data were binary and not valued, with a 0 indicating no tie between nodes and 1 indicating the presence of a connection between nodes.

## Data Analysis

Means, SDs, and percentages along with independent sample *t* tests were computed using SPSS (version 25; IBM Corp, Armonk, NY).<sup>28</sup> Separate linear network autocorrelation models were used to analyze the impact perceived barriers have on objectively measured PA while controlling for school, classroom, age, sex, and network effects. Linear network autocorrelation models were also used to determine if perceived barrier scores were clustered within networks while controlling for school, classroom, age, and sex.

Linear network autocorrelation modeling is a form of regression that specifically deals with the interdependent nature of network measures and determines the role network influences and connections may play in explaining specific outcome variables.<sup>29</sup> Cleaning and management of network data as well as linear network autocorrelation models were done using statnet package in R Studio.<sup>30</sup>

## Results

### Sample Characteristics

A total of 383 adolescents provided complete data across the 3 focal variables (perceived barrier scale, accelerometer, and sociocentric data). Adolescents in this sample were on average 10.77-years old ( $SD = 1.30$ ) and 51.4% were male; 67.6% were from primary classrooms ( $n = 259$ ) and 32.4% were from secondary classrooms ( $n = 124$ ). The mean density (number of connections divided by the total amount possible) for the 25 networks analyzed here was 0.34 ( $SD = 0.13$ ). The mean out degree (number of nominations sent per person) was 5.39 ( $SD = 2.54$ ). Participants achieved an average of 61.77 minutes of MVPA ( $SD = 54.21$ ) and 10,377.07 steps ( $SD = 3865.47$ ) daily. Male adolescents achieved significantly more minutes of MVPA (mean = 78.33,  $SD = 59.28$ ) when compared with female adolescents (mean = 44.29,  $SD = 41.78$ ;  $t(381) = 6.96$ ,  $P < .001$ ). Male adolescents also achieved significantly more steps per day (mean = 11,080.45,  $SD = 4006.30$ ) when compared with female adolescents (mean = 9627.46,  $SD = 3568.78$ ;  $t(381) = 4.00$ ,  $P < .001$ ).

### PA Network Autocorrelation

Linear network autocorrelation models were computed for both average MVPA per day and average steps per day. Both MVPA minutes and steps per day were significantly associated with network effects (ie, when controlling for other variables, an adolescent's friend's PA was associated with their PA). Sex was a significant factor in both models, as female adolescents achieved significantly less MVPA ( $\beta = -29.55$ ,  $P < .001$ ) and steps per day ( $\beta = -1562.77$ ,  $P < .001$ ) when compared with males, when controlling for other variables. Age was significantly associated with

more average steps per day ( $\beta = 499.55$ ,  $P < .001$ ). In addition, perceived social barrier subscale scores ( $\beta = 1019.35$ ,  $P = .01$ ) were significantly associated with more average steps per day; however, fitness-related barrier subscale scores ( $\beta = -1228.29$ ,  $P = .001$ ) were significantly associated with fewer average steps per day. See Table 1 for complete linear network autocorrelation models for objective PA measures.

### Perceived Barrier Network Autocorrelation

Separate linear network autocorrelation models were designed to determine whether perceived barrier subscale scores were significantly clustered within the network while controlling for school, classroom, age, and sex. Adolescent body-related ( $\beta = 0.02$ ,  $P = .001$ ) and social ( $\beta = 0.01$ ,  $P = .02$ ) barrier subscale scores were significantly associated with the scores of their connected peers. In other words, body-related and social subscale scores were clustered or grouped in a significant way throughout the network so that scores for these 2 subscales were more similar between adolescents who were friends than for those who were not. Table 2 contains linear network autocorrelation statistics for all subscales. These estimates should be interpreted as a measure of influence of friend's perceived barriers or spatial autocorrelation of perceived barriers.

## Discussion

This study aimed to understand the distribution of perceived barriers to PA throughout adolescent friendship networks. This is one of the first studies of this kind to examine the social autocorrelation or similarity of friends' perceived barriers to PA using SNA to our knowledge. This study also examined how these perceived barriers may impact objective PA measures within the same network while taking into consideration peer influences. Our results confirm our hypothesis that adolescent PA is more similar to that of their friends than nonfriends, while partially supporting our hypotheses that adolescents' PA is negatively associated with perceived social and fitness-related perceived barriers to PA; and adolescent's perceived barriers to PA are more similar to the perceived barriers of friends, compared with nonfriends for body-related and social barriers.

**Table 1 Linear Network Autocorrelation Models for Objective PA Measures**

	MVPA minutes/day			Steps/day		
	Estimate	SE	P value	Estimate	SE	P value
Control variables						
Age	1.99	1.44	.17	499.55	125.45	<.001*
Sex	-29.55	4.57	<.001*	-1562.77	393.63	<.001*
Perceived barriers						
Body	0.19	2.48	.94	-255.44	213.76	.23
Convenience	4.74	2.98	.11	42.96	257.45	.87
Resource	-3.89	4.24	.36	143.93	366.61	.69
Social	5.69	4.50	.21	1019.35	389.39	.01*
Fitness	-5.04	4.33	.24	-1228.29	373.58	.001*
Network effects	0.02	0.01	.004*	0.02	0.004	<.001*

Abbreviations: MVPA, moderate to vigorous PA; PA, physical activity.

Note: Models were controlled for school and classroom differences while not shown in estimates.

\*Significant at  $P < .05$ .



**Table 2 Linear Network Autocorrelation Network Statistics for Perceived Barrier Subscale Scores**

Barrier Subscale	Estimate ( $\beta$ )	SE	P value
Body related	0.02	0.01	.001*
Convenience	0.00	0.01	.74
Resource	0.01	0.01	.11
Social	0.01	0.01	.02*
Fitness	0.01	0.01	.24

Note: Autocorrelation models were controlled for school, classroom, age, and sex.

\*Significant at  $P < .05$ .

## Network Autocorrelation of PA

Models for both minutes of MVPA and steps per day exhibited significant network effects. Adolescents were significantly similar to their friends in their objectively measured PA, further suggesting that adolescents either select friends similar to them based on activity levels, and/or PA behaviors diffuse and spread across social connections.<sup>12</sup> This finding was unsurprising given similar patterns have not only been found in adolescent PA literature,<sup>12</sup> but concerning alcohol and substance use as well.<sup>31,32</sup>

Sex was the only other variable, besides network effects, significantly associated with minutes of MVPA. Male adolescents in our sample were significantly more active than their female counterparts, which is consistent with many studies showing disparity in PA achievement by sex.<sup>4</sup> Males in our sample (on average) attained the recommended number of steps per day and minutes of MVPA per day while females did not, on average. In contrast, age was significantly related to mean steps per day, while no significant association was shown between age and MVPA.

Within this sample, the mean steps model suggested older adolescents obtained more steps on average when controlling for other variables. This is different from the findings of Cooper et al.,<sup>4</sup> who found a decline in PA overtime. Due to this discrepancy, the authors completed a post hoc analysis using traditional linear regression without accounting for network effects. In the traditional linear regression model, older participants attained less steps while controlling for the same variables (eg, sex, perceived barriers to PA). Thus, the direction of the relationship changes once network effects are accounted for in the statistical model. It may be that the addition of network effects, and controlling for these effects, has potentially altered the association between steps and age. For example, generally steps tend to decline with age,<sup>4</sup> but when considering adolescents connect with others who are similar in age,<sup>33</sup> the effect seen by age alone is altered. Another explanation for the increase in steps could be that older adolescents were achieving more light-intensity PA, like walking to school, which would result in additional steps but not in increased MVPA. Future research should further explore this phenomenon.

Fitness-related perceived barrier subscale scores were significantly negatively associated with mean steps per day. Fitness-related perceived barrier items were related to perceiving one's self to be too overweight for PA and regarding PA as too hard or too much work. Overweight and obese adolescents have been shown to be less active when compared with normal-weight peers.<sup>34</sup> In addition, while these items cannot fully assess PA self-efficacy (overall belief in one's abilities) or perceived skill competency (ability to perform skills and tasks related to PA), adolescents who feel more confident in their skills related to PA have been reported to be more active, on average.<sup>35</sup> Therefore, those who report greater

fitness-related perceived barriers may simultaneously experience reduced PA self-efficacy, resulting in less PA altogether. In addition, this association between a lack of perceived skill competence is greater in overweight adolescents, which may amplify the impact of the items in this subscale.<sup>35</sup> These results suggest adolescents' perceived fitness barriers, while not significantly related to one's friends' perceived fitness barriers within the network, may significantly impact their PA.

Perceived social barrier subscale scores were associated with more steps per day on average, while they were not significantly associated with MVPA. This result suggests it is possible that adolescents who feel more perceived social barriers could be more "nomadic," without the stability of consistent friend groups or the peer support to engage in beneficial MVPA. Coupled with mental health implications of social isolation,<sup>36</sup> this result is not particularly encouraging, as increased intensity of activity (ie, MVPA) has been shown to provide more health benefits, especially among adolescents.<sup>37</sup> On the other hand, it is possible that perceived social barriers to PA are offset by social expectations to be active. Several studies suggest PA behaviors are driven by peer and family expectation,<sup>38,39</sup> which could even out any deterrence from PA resulting from perceived social barriers.

## Network Autocorrelation of Perceived Barriers

Perceived body-related and social barrier subscales were significantly clustered within the network when controlled for school, classroom, sex, and age. In other words, adolescents' perceived body-related and social barrier scores were significantly associated with the scores of their friends' perceived barrier scores. Perceived body-related barriers in this scale imply a level of body dissatisfaction, or negative feeling toward how one's body feels or looks.<sup>40</sup> Body dissatisfaction has been associated with social comparison among adolescents, specifically adolescent girls.<sup>41</sup> Previous research using SNA suggests that network properties and social ties are related to body dissatisfaction within a network, which may help explain the clustering of perceived body-related barriers within this adolescent network.<sup>42</sup>

Perceived social barriers in this scale primarily dealt with peer influence on PA, such as "My friends don't like to be physically active" or "I don't have anyone to be physically active with." Consistent with previous adolescent PA network literature,<sup>12</sup> this finding suggests adolescents likely adopt the behaviors and attitudes of their close social contacts, leaving those who do not prefer activity to connect with others who feel similarly. This may be a form of homophily, or the natural propensity of individuals to be friends with others similar to themselves.<sup>33</sup> While this study cannot infer whether or not the similarity is due to selection of friends due to similarity or becoming more like your friends over time,<sup>15,43</sup> the fact perceived social barriers to PA may be clustered within school networks may lead to more effective programs to remediate these perceived barriers and increase PA in adolescents. Researchers and practitioners may wish to identify these problematic clusters for targeted programs.<sup>44</sup>

These results further implicate the role of networks in adolescent PA behaviors. Thus, researchers and practitioners aiming to reduce perceived barriers to PA should pay attention to the impact peers can have on perceived barrier stability (either by reinforcement of perceived barriers or support in eliminating perceived barriers), particularly those related to social and body concerns. In this respect, it may be more beneficial to approach the removal of perceived barriers from a network perspective. For example,

tailoring alternative activities for groups of adolescents who prefer not to be active could be more impactful than activities intended for the whole network. Furthermore, using SNA to identify opinion leaders within adolescent cliques might be a powerful intervention tool in reducing perceived barriers to PA and increasing PA behavior.<sup>45,46</sup> The identification of opinion leaders has been done in simulation studies regarding adolescent PA but have not been done in regards to perceived PA barriers.<sup>47</sup>

## Limitations

As this study only analyzed one wave of the data specific to the testing of perceived barriers to PA and is subsequently cross-sectional, the authors are only able to determine associations between these variables and cannot determine causation, or are unable to determine differences between selection and influence effects. In other words, the authors cannot determine whether the similarity reported here is because adolescents choose friends based on perceived barrier similarity or if they become more similar to their friends overtime. Future research may wish to use more advanced modeling techniques like stochastic actor modeling to parse out these effects within a complete longitudinal analysis.<sup>48</sup>

It should be noted that because this study uses sociocentric network analysis, the generalizability of the study is complex. Typically, in sociometric studies, the social dynamics are specific to the network in question. This study did benefit from surveying 25 classrooms in 12 different schools (both primary and secondary level) and controlling for these factors, which strengthens the generalizability to other networks. Similarly, it may be possible that some of the adolescents who chose not to participate could be key members of the social dynamic of the classroom. As stated in the methods, only classrooms with at least 60% participation rates were included in the analysis to ensure more representative networks.

## Conclusions

This research suggests adolescents' perceived barriers to PA can be impacted by social connections. Specifically, patterns of perceived social and body-related barriers to PA were found in this network of adolescents. In other words, scores from these 2 subscales were more similar between friends than adolescents who were not friends. In addition, perceived barrier subscale scores, as well as network effects, significantly impacted adolescent PA levels within this study. Overall, results suggest that considering an adolescent's friendship network could be an effective strategy in increasing activity levels at the individual and interpersonal levels.

## Acknowledgment

The research leading to these results received funding from the European Research Council (ERC) under the European Union's Seventh Framework Programme (FP7/2007-2013)/ERC grant agreement n° 617253. The findings and conclusions of this research are those of the authors and do not necessarily represent the official position of the ERC.

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