Buffer Zones in Basketball

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Injuries caused by inadequate buffer zones

- Lebron James caused a concussion to a spectator.
- Fatal accident: In 1997, 8th grade Lamar Pope went head first into the gym wall less than 5 feet from the end line as playing basketball.
- In 2001, 14 year old Katie Patrick fell backwards and hit her head on the unpadded metal wall less than 4 feet from the end line. She sustained a traumatic brain injury.

"... the lack of a sufficient buffer zone was alleged to have been the primary causes of injury in 67% of basketball lawsuits."
Buffer zone is the space between the activity area and any obstructions such as walls, benches and equipment.

Figure: National Federation of State High School Association (NFHS) court and field diagram guide.
Current standards and regulations

- National Federation of State High School Associations Basketball Rules.. at least 3 feet (preferably 10 feet)
- National Collegiate Athletic Association (NCCA) Mens and Womens Basketball Rules Committees and the Amateur Athletic Union (AAU) recommend "... at least 10 feet of open space between the boundary lines and the seating."
- American Alliance for Health, Physical Education, Recreation and Dance (AAHPERD) recommends at least 10 feet clear space beyond the end lines with a very minimum of 6 feet with full wall padding.

- Is the space sufficient? if not, then what should be the minimum buffer zones?
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Physics behind of walking

Figure: F(R) in the right graph is the normal force on right foot, which is measured by force plate. [1]

\[
\overrightarrow{GRF} = \overrightarrow{N} + \overrightarrow{f_s}
\]

where \( GRF \) is Ground Reaction Force.

Physics model of walking - simple pendulum

- Speed limit of walking depends on the leg length \( L_{\text{leg}} \).
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  v_{\text{max}} = \sqrt{gL_{\text{leg}}}
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Running

**Figure:** The left figure shows the normal force when the running speed is 6 m/s. [1]

- Stride length (m)
- Stride frequency (Hz)
- Duty factor
Duty factor

Duty factor ”D” is the fraction of the stride period at which one foot is in contact with the ground.

- \(D \approx 0.3\) as the speed of 5m/s; \(D \approx 0.2\) as the speed of 9m/s. [1]
- \(D = 0.394Fr^{-0.174}\) (1)

where Froude number, \(Fr = v^2/(gL_{leg}).\) [2]

Study design

What is the minimum first stride length $x_1$ as athletes slow down from their highest speeds in court?

- The contact time calculated from the stride before slowing down =
  The contact time calculated from the stride after slowing down

$$\frac{l}{v_0}D_0 = \frac{x_1}{v_1}D_1$$  \hspace{1cm} (2)

where "l" is the stride length before slowing down.
$v_0$, $v_1$ and $D_0$, $D_1$ are the speeds before and after slowing down and their related duty factors.

- "l" is measured as participants run with a regular pace in the court.
- $v_0$ is measured as the highest speed in the court.
- $v_1$?
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Study design

Momentum - Impulse Theorem

\[ f_s \Delta t = m \Delta v \]  \hspace{1cm} (3)

\[ v_{i+1} = v_i - \frac{f_{s,i}}{m} \Delta t, \text{ Limitation: measurement of } f_{s,i}. \]  \hspace{1cm} (4)

\[ v_{i+1} = v_i - \frac{\mu_s N}{m} \Delta t, \text{ Estimation: } f_{s,i} = f_{\text{max},s,i} = \mu_s N. \]  \hspace{1cm} (5)

- Normal force \( N \) is measured in high jump by 2-axis force plate.
- Approximate static friction coefficient between basketball shoes and wooden floor is 1.0 \( \sim \) 1.2 [3, 4].

Measurement

- 11 basketball players participated in the investigation in fall 2016. Among the 11 participants, one of them played college basketball, seven of them played varsity high school basketball for an average of 3.3 years, and four of them played basketball only recreationally.

- Data collection
  Prior to the game: athlete’s height, weight, stride length, ground reaction force in high jump, reaction time.
  Throughout the game: athlete’s speed, number of occasions participants went out of bounds, and the distance they travelled.
Force plate

## Results and conclusions

### Data from direct measurement

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Sideline</th>
<th>Loose ball chase</th>
<th>Lay up</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of data, N</strong></td>
<td>19</td>
<td>5</td>
<td>11</td>
<td>10</td>
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<tr>
<td><strong>Out of bound distance, x (ft.)</strong></td>
<td>5.18</td>
<td>3.28</td>
<td>5.15</td>
<td>5.00</td>
</tr>
</tbody>
</table>
## Results and conclusions

Data from modeling Buffer zone space $x_{total}$ were calculated.

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>3 point line</th>
<th>Half court</th>
<th>Full court</th>
<th>Lay up</th>
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</thead>
<tbody>
<tr>
<td>Number of data, N</td>
<td>35</td>
<td>13</td>
<td>11</td>
<td>12</td>
<td>16</td>
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<tr>
<td>$v_0$ (mph)</td>
<td>19.57</td>
<td>17.38</td>
<td>20.09</td>
<td>21.64</td>
<td>18.88</td>
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<tr>
<td>$v_1$ (mph)</td>
<td>15.37</td>
<td>12.46</td>
<td>16.04</td>
<td>17.96</td>
<td>14.47</td>
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<tr>
<td>$x_1$ (ft.)</td>
<td>4.69</td>
<td>4.13</td>
<td>4.79</td>
<td>5.05</td>
<td>4.53</td>
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<tr>
<td>$v_2$ (mph)</td>
<td>11.18</td>
<td>7.54</td>
<td>11.99</td>
<td>14.29</td>
<td>10.06</td>
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<tr>
<td>$x_2$ (ft.)</td>
<td>3.05</td>
<td>2.10</td>
<td>3.25</td>
<td>3.71</td>
<td>2.79</td>
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<tr>
<td>$v_3$ (mph)</td>
<td>6.96</td>
<td>2.62</td>
<td>7.94</td>
<td>10.63</td>
<td>5.64</td>
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<td>$x_3$ (ft.)</td>
<td></td>
<td>1.87</td>
<td>2.49</td>
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<tr>
<td>$v_4$ (mph)</td>
<td></td>
<td></td>
<td>3.87</td>
<td>6.96</td>
<td></td>
</tr>
<tr>
<td>$x_{total}$ (ft.)</td>
<td>7.74</td>
<td>6.27</td>
<td>9.88</td>
<td>11.25</td>
<td>7.32</td>
</tr>
</tbody>
</table>
THANK YOU!!