

How do people of different age group tackle staircase?



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Declaration

I declare that this written submission represents my ideas in my own words and where others ideas or words have been included, I have adequately cited and referenced the original sources.

I also declare that I have adhered to all the principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission.

I understand that any violation of the above will be cause for disciplinary action by the institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Approval

This DRS titled “How do people of different age group tackle staircase” was prepared and submitted by Irshath Ahamed K in fulfilment of the requirement of the degree masters in design in Industrial design. It has been examined and is recommended for approval and acceptance.

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Abstract

A comprehensive movement analysis of staircase climbing can help in the research of several rehabilitation methods. This research study provides the investigations and observations of a human's lower extremity during ascent and descent walking at different inclinations. In addition to this, the analysis of staircase ascent and descent can be useful in the design of private and public environment where staircase is employed. Several normal subjects were ascended and descended a flight of staircase at similar inclinations for the study. Observations such as the subject's starting position and reaching position, hand railing usage, ascend and descent speed, Foot position, knee position, Body position, vision, stuttering were noted also their psychological feel on staircase, handrail material and also their problems were also interviewed.

Methods

The Investigations and Observations were done in three types of methods such as Interviews, Simulations and candidly observing people at public places and homes. The observations were done for different age groups such as kids, adults and elders respectively.

The Participants list is given below.

Participant List Age category: Kids						
Sl. No	Name	Gender	Age	Lighting	Footwear	Test type
1	Sohail	M	10	Good	Shoes with rubber sole	Candid
2	Muhammed	M	12	Good	Rubber Sole Slippers	Interview & Simulation
3	Zeena	F	11	Moderate	Rubber sole sandals	Simulation
4	Ziad	M	14	Good	Sandals	Interview & Simulation
5	Reshma	F	13	Moderate	Sandals	Interview & Simulation
6	Adil	M	10	Good	Shoes	Simulation
7	Shafath	M	14	Good	Shoes with rubber sole	Interview & Simulation
8	Joudath	M	12	Good	Flip Flops	Candid
9	Zumana	F	16	Moderate	Sandals	Interview & Simulation
10	Humaira	F	11	Good	Barefoot	Candid
11	Jasra	F	13	Good	Sandals	Interview & Simulation

Participant List Age category: Adults						
Sl. No	Name	Gender	Age	Lighting	Footwear	Test type
1	Abijit	M	27	Good	Sandals	Interview & Simulation
2	Ankur	M	26	Moderate	Sandals	Interview & Simulation
3	Negi	M	25	Good	Shoes	Interview & Simulation
4	Deepak	M	25	Good	Sandals	Interview & Simulation
5	Dinesh	M	24	Good	Flip Flops	Interview & Simulation
6	Pooja	F	23	Moderate	Sandals	Interview & Simulation
7	Kumaran	M	23	Moderate	Sandals	Interview & Simulation
8	Gautam	M	25	Good	Sandals	Interview & Simulation
9	Naveen	M	24	Good	Sandals	Interview & Simulation
10	Devika	F	23	Moderate	Sandals	Interview & Simulation
11	Shankar	M	26	Moderate	Flip Flops	Interview & Simulation
12	Dinesh Raj	M	27	Good	Sandals	Interview & Simulation
13	Vignesh	M	28	Good	Sandals	Interview & Simulation
14	Irshath	M	23	Good	Flip Flops	Interview & Simulation

Participant List Age category: Adults						
Sl. No	Name	Gender	Age	Lighting	Footwear	Test type
1	Jarina	F	57	Good	Sandals	Interview & Simulation
2	Hajira	F	64	Good	Sandals	Interview & Simulation
3	Malika	F	67	Good	Sandals	Interview & Simulation
4	Fathima	F	65	Moderate	Sandals	Interview & Simulation
5	Jamila	F	79	Good	Sandals	Interview & Simulation
6	Ismail	M	74	Good	Flip Flops	Interview & Simulation
7	Rahamathnisa	F	49	Good	Sandals	Interview & Simulation
8	Abdul salam	M	80	Good	Flip Flops	Interview & Simulation
9	Fathima	F	78	Good	Sandals	Interview & Simulation
10	Yousuff	M	71	Moderate	Flip Flops	Interview & Simulation
11	Jaleel	M	51	Moderate	Shoes	Interview & Simulation
12	Bapat	M	66	Good	Flip Flops	Interview & Simulation
13	Mohan	M	56	Good	Shoes	Interview & Simulation

Table 1: List of Participants

What's a staircase?

A stairway, staircase, stairwell, flight of stairs, or simply stairs is a construction designed to bridge a large vertical distance by dividing it into smaller vertical distances, called steps. Stairs may be straight, round, or may consist of two or more straight pieces connected at angles.

Components of a typical staircase

A stair, or a stair step is one step in a flight of stairs. In buildings, staircase is a term applied to a complete flight of steps between two floors. A stair flight is a run of stairs or steps between landings. A staircase or stairway is one or more flights of stairs leading from one floor to another, and includes landings, newel posts, handrails, balustrades and additional parts. A stairwell is a compartment extending vertically through a building in which stairs are placed. A stair hall is the stairs, landings, hallways, or other portions of the public hall through which it is necessary to pass when going from the entrance floor to the other floors of a building. Box stairs are stairs built between walls, usually with no support except the wall strings.

Stairs may be in a straight run, leading from one floor to another without a turn or change in direction. Stairs may change direction, commonly by two straight flights connected at a 90° angle landing. Stairs may also return onto themselves with 180° angle landings at each end of straight flights forming a vertical stairway commonly

used in multi-story and high-rise buildings. Many variations of geometrical stairs may be formed of circular, elliptical and irregular constructions.

Staircase Anatomy

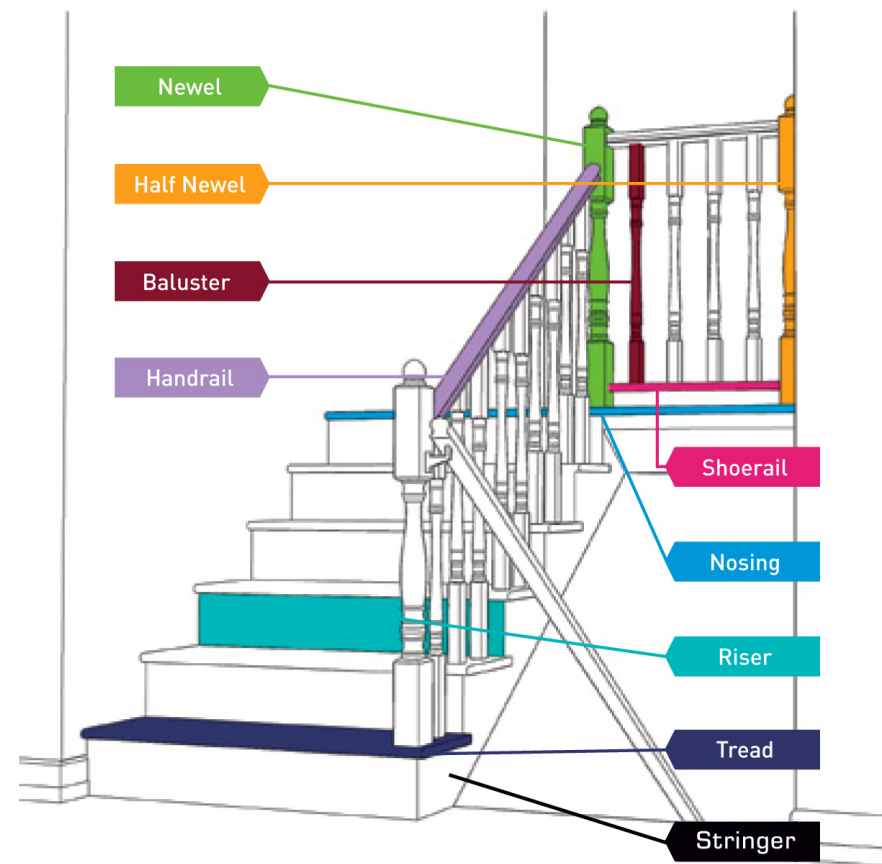


Figure 1: Components of a staircase

Step

Each step is composed of tread and riser.

Tread

The part of the stairway that is stepped on. It is constructed to the same specifications (thickness) as any other flooring. The tread "depth" is measured from the outer edge of the step to the vertical "riser" between steps. The "width" is measured from one side to the other.

Riser

The vertical portion between each tread on the stair. This may be missing for an "open" stair effect.

Nosing

An edge part of the tread that protrudes over the riser beneath. If it is present, this means that, measured horizontally, the total "run" length of the stairs is not simply the sum of the tread lengths, as the treads overlap each other.

The railing system

The balustrade is the system of railings and balusters that prevents people from falling over the edge.

Railing or Handrail

The angled member for handholding, as distinguished from the vertical balusters which hold it up for stairs that are open on one side; there is often a railing on both sides, sometimes only on one side or not at all, on wide staircases there is sometimes also one in the middle, or even more. The term "banister" is sometimes used to

mean just the handrail, or sometimes the handrail and the balusters or sometimes just the balusters.

Baluster

A term for the vertical posts that hold up the handrail. Sometimes simply called *guards* or *spindles*. Treads often require two balusters. The second baluster is closer to the riser and is taller than the first. The extra height in the second baluster is typically in the middle between decorative elements on the baluster. That way the bottom decorative elements are aligned with the tread and the top elements are aligned with the railing angle.

What is staircase climbing?

Staircase climbing is nothing but climbing a flight of stairs. Stair climbing expends more energy per minute than jogging, is readily available to most of the population, and the activity can be accumulated throughout the day as part of work, leisure and home life. The University of Birmingham's research indicates that stair climbing interventions produce a 6.4% increase in usage of public access stairs, with a 12.3% increase recently reported in one workplace. Stair climbing represents a simple form of preventive medicine for weight gain. An average weight man for example, i.e. 80 kg, who climbs stairs in his home an extra ten times each day, accumulates energy expenditure equivalent to 1.3kg of fat over a year.

How do people Climb Staircase?

Firstly, it is important for one to know about how a humans climb staircase. Things like how they use their hands, legs, body and eyes work individually as well as integration of all the parts of the body work. It is also important to understand the biomechanics of human body to fully understand how each age group tackle a typical staircase.

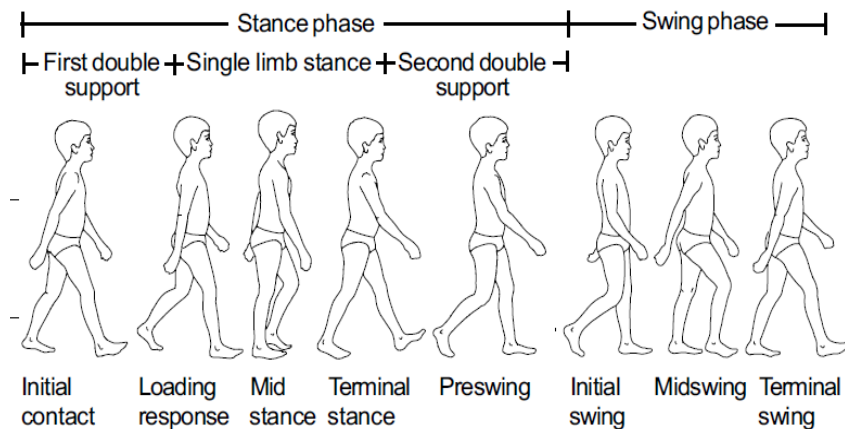


Figure 2: Phases of walking

Following is the break down of the technique of stair-climbing in general.

In terms of what moves our body from one step to the next, there are two main actions performed in stair climbing: **hip**

extension (where we pull the thigh back and down, away from our torso) and **knee extension** (where we straighten the leg at the knee joint).

Of course, when we move the other leg forwards to the next step, you are flexing at the knee and the hip, but the actions that actually move our body up the staircase are **extension** and **extension**. We straighten the knee, and straighten the hip, and this moves our body through space. It is easy not to think in these terms, because as we move forward we think of the leg that *is* moving forward, but of course it is *the leg that remains on the ground* that propels our body forwards and in this case upwards, and it is in the action of this leg that we see either efficient or inefficient movement patterns expressed.

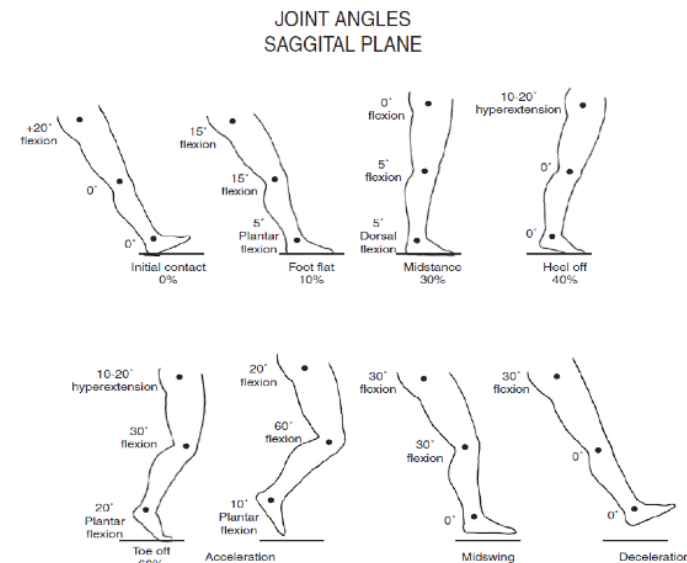


Figure 3: Angles of walking phases

For the sake of simplicity, we can think of it this way: *extension* occurs when a joint opens and *flexion* occurs when it closes. For whatever reason, many of us rely more on knee extension than deriving power from the hips and buttocks, which is to our detriment. Many of us have weak buttocks, relative to our thigh muscles, but as to why this is? There are many theories, ranging from too much sitting, to too much imbalanced sports-playing.

A survey on use-preference of staircase or elevator.

As staircase plays an important role in vertical transportation of building, the research of human behaviour on it will benefit on promoting the efficiency of transportation, comfort and experience level.

Through the following analysis on different use frequencies and different behaviours of different people with a scissor staircase and an elevator, this survey has found some use-preferences and tries to quantify the psychological effect, with the aim giving some reference on staircase-elevator choosing for buildings.

Method: This survey was taken in the main building where there is an elevator just adjacent to the staircase. And then IDC building where the elevator is kept away from the staircase. The methods of survey include counting and observation with photography.



Figure 4 & 5: Experiment Location - IIT Main building

YA-Younger adults (18-40) OA-Older adults (40+)

Includes office employees, Security personnel and Students.

Results from the Main building at IIT.

Survey Taken on Monday February 6th 2017 (9AM)

Total number of people went upstairs/downstairs: 38 (23 YA - 15 OA)

No. of people who used staircase: 16 (14 YA - 2 OA) (42%)

No. of people who used elevator: 22 (9 YA - 13 OA) (58%)

No. of people who went to first floor: 15 (11 YA - 4 OA)

No. of people who used staircase: 9 (8 YA - 1 OA) (60%)

No. of people who used elevator: 6 (3 YA - 3 OA) (40%)

No. of people who went to Second floor: 23 (9 YA - 14 OA)

No. of people who used staircase: 7 (7 YA - 0 OA) (30%)

No. of people who used elevator: 16 (2 YA - 14 OA) (70%)

Survey Taken on Tuesday February 7th 2017 (9AM)

Total number of people went upstairs/downstairs: 41 (27 YA - 14 OA)

No. of people who used staircase: 17 (17 YA - 0 OA) (40%)

No. of people who used elevator: 24 (10 YA - 14 OA) (60%)

No. of people who went to first floor: 17 (13 YA - 4 OA)

No. of people who used staircase: 11 (10 YA - 1 OA) (64%)

No. of people who used elevator: 6 (3 YA - 3 OA) (36%)

No. of people who went to Second floor: 24 (7 YA - 17 OA)

No. of people who used staircase: 6 (6 YA - 0 OA) (25%)

No. of people who used elevator: 18 (1 YA - 17 OA) (75%)

Results from the IDC building at IIT.

Survey Taken on Monday February 6th 2017 (2PM)

Total number of people went upstairs/downstairs: 69 (49 YA - 20 OA)

No. of people who used staircase: 46 (38 YA - 8 OA) (66%)

No. of people who used elevator: 23 (11 YA - 12 OA) (34%)

No. of people who went to first floor: 35 (21 YA - 14 OA)

No. of people who used staircase: 30 (19 YA - 11 OA) (85%)

No. of people who used elevator: 5 (2 YA - 3 OA) (15%)

No. of people who went to Second floor: 34 (28 YA - 6 OA)

No. of people who used staircase: 16 (13 YA - 3 OA) (47%)

No. of people who used elevator: 18 (15 YA - 3 OA) (53%)

Survey Taken on Tuesday February 7th 2017 (2PM)

Total number of people went upstairs/downstairs: 71 (53 YA - 18 OA)

No. of people who used staircase: 50 (41 YA - 9 OA) (70%)

No. of people who used elevator: 21 (12 YA - 9 OA) (30%)

No. of people who went to first floor: 43 (33 YA - 10 OA)

No. of people who used staircase: 33 (27 YA - 6 OA) (76%)

No. of people who used elevator: 10 (6 YA - 4 OA) (24%)

No. of people who went to Second floor: 28 (19 YA - 9 OA)

No. of people who used staircase: 17 (13 YA - 4 OA) (60%)

No. of people who used elevator: 11 (6 YA - 5 OA) (40%)



Figure 6: Experiment location - Elevator at IDC



Figure 7: Experiment location – Staircase at IDC

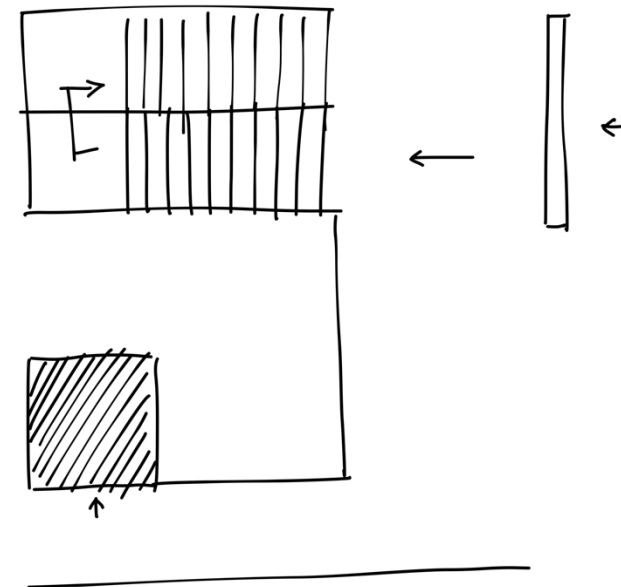


Figure 7b: The Elevator is kept away from the staircase the natural instinct would be to approach the staircase at first.

Inference: This observation shows that the most of the Older adults prefer elevator no matter what the floor level is. While the No. of younger adults decreases as the floor level decreases.

- The total number increases as the floor increases
- The total number of older adults is always higher on elevators
- The total number of younger adults is always higher on staircases
- Older adults prefer elevator even if the elevator is kept further from the staircase

Where do people look for a staircase in a typical public building?

Many times people are not aware of the presence of a stair. The steps are often the same colour and texture as surrounding surfaces (top and bottom levels) and they are often poorly lit and marked, making them difficult to see. This is probably the primary reason that a disproportionate number of falls occur in stair runs of just one or two steps. It is often not obvious to a person that there is a change in the floor level.

Walk through the front door of a typical production home and the first thing you'll see is the staircase. It's a long-held belief that this layout, with the base of the stairs located just inside the front entrance, gives the foyer a traditional look that homeowners want.

Participant List Age category: Adults				
Sl. No	Name	Gender	Age	Where would you look for a staircase
1	Abijit	M	27	At the Entrance
2	Ankur	M	26	At the Entrance
3	Negi	M	25	At the Entrance
4	Deepak	M	25	At the Entrance
5	Dinesh	M	24	At the Entrance
6	Pooja	F	23	At the Entrance
7	Kumaran	M	23	At the Entrance
8	Gautam	M	25	At the Entrance
9	Naveen	M	24	At the Entrance
10	Devika	F	23	At the Entrance
11	Shankar	M	26	At the Entrance
12	Dinesh Raj	M	27	At the Entrance
13	Vignesh	M	28	Outside the building
14	Irshath	M	23	At the Entrance

Participant List Age category: Adults				
Sl. No	Name	Gender	Age	Where would you look for a staircase
1	Jarina	F	57	At the Entrance
2	Hajira	F	64	At the Entrance
3	Malika	F	67	At the Entrance
4	Fathima	F	65	Outside the building
5	Jamila	F	79	At the Entrance
6	Ismail	M	74	At the Entrance
7	Rahamathnisa	F	49	At the Entrance
8	Abdul salam	M	80	At the Entrance
9	Fathima	F	78	At the Entrance
10	Yousuff	M	71	At the Entrance
11	Jaleel	M	51	At the Entrance
12	Bapat	M	66	Outside the building
13	Mohan	M	56	At the Entrance

Table 2: Preferred Staircase location by the participants.

A part of the questionnaire is where would they look for a staircase in-case if they are new to a building. Most of the people said that they'd like the staircase to be in-front of the building if its outside and just inside the entrance if its outside. When asked if they cannot find the staircase at the front most of them said that they'd ask for it to anyone at the entrance.

As far as a personal housing are concerned, while a graceful stairwell at a home's entry has appeal, I personally believe this design loses out when it comes to functionality and use of space. Having said this in a public building the staircase should always be placed at the entrance.

Gait Cycle

A key tool for communication and identifying and defining locomotor tasks such as stair ambulation is the gait cycle. During stair ascent and stair descent, the lower limbs move in a cyclical pattern similar to that of level walking, and the gait cycle for both tasks is divided into two distinct phases: the stance (support) phase and the swing phase. Each of the phases is characterized by a distinct length of time spent in the swing and stance phases.



Figure 8 & 9: Gait cycle dissection of a kid while ascending.

Method

Gait cycle time were calculated using a simple stop watch by analysing the videos as well as real time calculation. Slow motion videos were analysed to fully understand the gait cycle.

Older Adults: Stair ascent – 2.5 seconds for stance and 3.5 seconds for swing (52% stance: 58% swing) and stair descent – 1 second for stance and 2.6 seconds for swing (28% stance: 72% swing)

Younger Adults: Stair ascent - .18 seconds for stance and .6 seconds for swing (23% stance: 77% swing) and stair descent- .17 seconds for stance and .28 seconds for swing (38% stance: 62% swing)

Kids: Stair ascent - .2 seconds for stance and .65 seconds for swing (24% stance: 76% swing) and stair descent .16 seconds for stance and .3 seconds for swing (35% stance: 65% swing)



Figure 10 & 11: Gait cycle dissection of a kid while descending

Participant List					
Age category: Kids					
Sl. No	Name	Gender	Age	Ascent Time in sec (stance and swing)	Descent Time in sec (stance and swing)
1	Sohail	M	10	.20 and .65	.16 and 30
2	Muhammed	M	12	.25 and .68	.20 and 35
3	Zeena	F	11	.22 and .70	.16 and 35
4	Ziad	M	14	.28 and .65	.16 and 28
5	Reshma	F	13	.20 and .75	.23 and 36
6	Adil	M	10	.28 and .55	.21 and 34
7	Shafath	M	14	.25 and .68	.15 and 31
8	Joudath	M	12	.34 and .71	.18 and 38
9	Zumana	F	16	.15 and .60	.14 and 33
10	Humaira	F	11	.25 and .65	.19 and 30
11	Jasra	F	13	.20 and .60	.16 and 30

Table 3: Time taken for gait cycle in children

Participant List					
Age category: Younger Adults					
Sl. No	Name	Gender	Age	Ascent Time in sec (stance and swing)	Descent Time in sec (stance and swing)
1	Abijit	M	27	.18 and .60	.27 and .29
2	Ankur	M	26	.20 and .65	.17 and .28
3	Negi	M	25	.17 and .66	.18 and .30
4	Deepak	M	25	.14 and .64	.21 and .31
5	Dinesh	M	24	.21 and .71	.18 and .34
6	Pooja	F	23	.20 and .60	.16 and .24
7	Kumaran	M	23	.17 and .59	.21 and .37
8	Gautam	M	25	.21 and .59	.19 and .29
9	Naveen	M	24	.18 and .60	.23 and .38
10	Devika	F	23	.18 and .68	.15 and .29
11	Shankar	M	26	.28 and .66	.17 and .28
12	Dinesh Raj	M	27	.16 and .64	.19 and .38
13	Vignesh	M	28	.16 and .69	.23 and .35
14	Irshath	M	23	.20 and .60	.17 and .31

Table 4: Time taken for gait cycle in younger adults

Participant List					
Age category: Older Adults					
Sl. No	Name	Gender	Age	Ascent Time in sec (stance and swing)	Descent Time in sec (stance and swing)
1	Jarina	F	57	2.1 and 2.9	1.0 and 2.6
2	Hajira	F	64	2.6 and 4.0	1.2 and 2.8
3	Malika	F	67	3.1 and 4.4	1.0 and 2.4
4	Fathima	F	65	2.7 and 3.8	1.2 and 2.8
5	Jamila	F	79	2.5 and 3.6	1.4 and 2.7
6	Ismail	M	74	2.8 and 3.6	1.5 and 2.1
7	Rahamathnisa	F	49	2.6 and 3.9	0.7 and 1.5
8	Abdul salam	M	80	2.8 and 4.0	1.2 and 2.0
9	Fathima	F	78	2.0 and 3.1	1.0 and 2.6
10	Yousuff	M	71	2.9 and 3.8	1.1 and 2.4
11	Jaleel	M	51	2.2 and 3.0	0.9 and 2.0
12	Bapat	M	66	2.5 and 3.5	1.1 and 1.9
13	Mohan	M	56	2.5 and 3.5	1.1 and 2.2

Table 5: Time taken for gait cycle in older adults

In terms of stair usage, the stance and swing phases are further subdivided into three sub-phases during support and two sub-phases during swing. The stance phase during stair ascent is subdivided into three specific sub-phases:

- 1) weight acceptance (WA: the initial movement of the body into an optimal position to be pulled up).
- 2) pull up (PU: the main progression of ascending from one step to the subsequent step).
- 3) and forward continuance (FC: the complete ascent of a step has occurred and continued progression forward occurs).

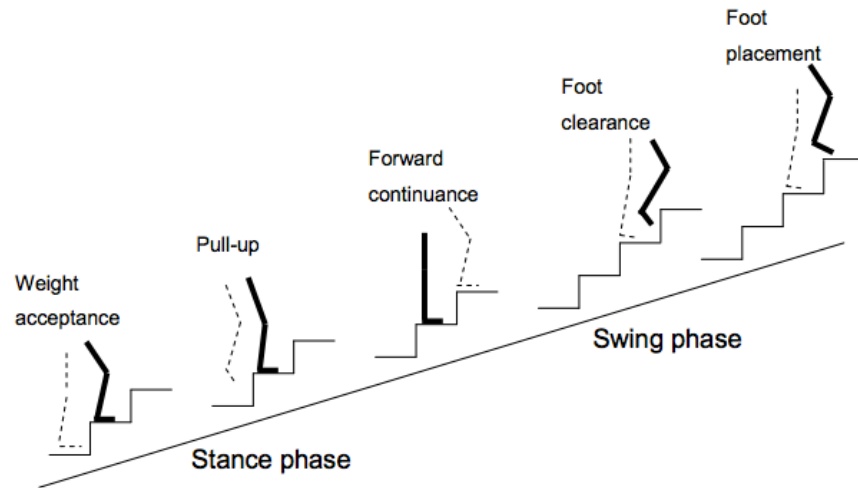


Figure 12: Types of gait cycle while ascending

The swing phase is subdivided into two specific sub-phases:

- 1) foot clearance (FCL: the bringing of the leg up and over to the next step while keeping the foot clear of the intermediate step)
- 2) foot placement (FP: simultaneous lifting of the swing leg and leg positioning for foot placement on step).

Similar to ascent, the stance phase of descent is divided into three specific sub-phases:

- 1) weight acceptance.
- 2) forward continuance (FC: the commencement of 13 single leg support and the body begins to move forward)
- 3) controlled lowering (CL: the major portion of progression when descending from one step to the next).

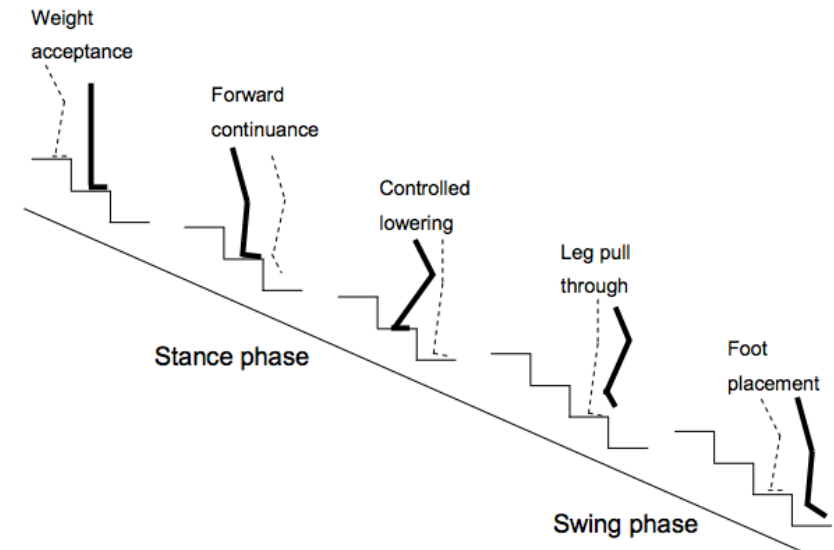


Figure 13: Types of gait cycle while descending

The swing phase of descent is subdivided into two specific sub-phases:

- 1) leg pull through (LP: the swing through of the leg)
- 2) preparation for foot placement (FP).

Stair Ambulation pattern

Stair ambulation is performed with ease by young healthy persons; however, the task can be quite challenging for older adults due to the age-related biomechanical, physiological, and psychological changes that occur.

There were two types of ascending and descending pattern found. **Step over step** and **step by step**. In short the Older adults who are over 70 adopted step by step while almost everyone else adopted step over step pattern.

The Older adults carefully noted where they are keeping their foot and how they are keeping their foot. They tend to make sure that they're foot is safely placed with little to no space left from their heel to the riser. While the rest of the people subconsciously knew where they're placing their foot and how much clearance is left.

Research is still needed to understand dynamic stability during stair ambulation in older adults as well as various other populations. Furthermore, analysis of dynamic stability of different stair ambulation strategies employed by older adults may provide further insight for why these strategies are chosen and how they aid in the reduction of falls.

Alternate stair ambulation

Generally speaking, alternate gait patterns (use of handrail and/or step-by-step pattern, placement of both feet on the same step prior to ascending or descending) adopted by older adults during stair ambulation tends to deviate from the traditional step over-step pattern used by young healthy individuals.

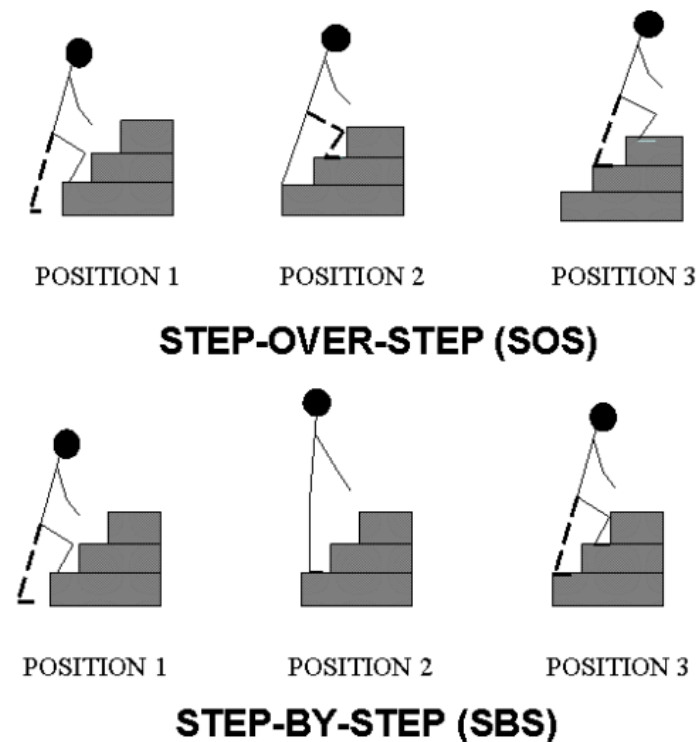


Figure 14: Different patterns in stair ambulation

Step By Step (SBS)



Figure 15: Step By Step as found in Older adults



Figure 16: Step By Step as found in Older adults



Step Over Step (SOS)



Figure 17: Step Over Step as found in kids



Figure 18: Step Over Step as found in Younger adults

Participant List					
Age category: Adults					
Sl. No	Name	Gender	Age	Lighting	Ambulation Pattern
1	Jarina	F	57	Good	Step over Step
2	Hajira	F	64	Good	Step over Step
3	Malika	F	67	Good	Step over Step
4	Fathima	F	65	Moderate	Step over Step
5	Jamila	F	79	Good	Step by Step
6	Ismail	M	74	Good	Step by Step
7	Rahamathnisa	F	49	Good	Step over Step
8	Abdul salam	M	80	Good	Step by Step
9	Fathima	F	78	Good	Step by Step
10	Yousuff	M	71	Moderate	Step over Step
11	Jaleel	M	51	Moderate	Step over Step
12	Bapat	M	66	Good	Step over Step
13	Mohan	M	56	Good	Step over Step

Table 6: Different types of stair ambulation pattern found under Older adults (marked in yellow are Older adults over 75)

Fear of falling

Fear of falling has been identified as a key health issue amongst older adults, with an estimated prevalence of 50 percent of the people

interviewed. Fear of falling is often associated with poor health status, impaired balance, gait abnormalities, sex, history of falls etc.

Having said that The fear of fall is completely absent in younger adults as well kids since they're confident with their stair ambulation.

Participant List						
Age category: Adults						
Sl. No	Name	Gender	Age	Lighting	Test type	Fear of fall
1	Jarina	F	57	Good	Interview & Simulation	Confident
2	Hajira	F	64	Good	Interview & Simulation	Confident
3	Malika	F	67	Good	Interview & Simulation	Confident
4	Fathima	F	65	Moderate	Interview & Simulation	Confident
5	Jamila	F	79	Good	Interview & Simulation	Poor Physical Health, Higher age
6	Ismail	M	74	Good	Interview & Simulation	History of fall, Higher levels of anxiety
7	Rahamathnisa	F	49	Good	Interview & Simulation	Confident
8	Abdul salam	M	80	Good	Interview & Simulation	Increased Age, Poor Balance
9	Fathima	F	78	Good	Interview & Simulation	Balance abnormalities
10	Yousuff	M	71	Moderate	Interview & Simulation	Frailty, Feels weak after climbing staircase, Previous injuries to ankle, Pains increases over time
11	Jaleel	M	51	Moderate	Interview & Simulation	Confident
12	Bapat	M	66	Good	Interview & Simulation	Confident
13	Mohan	M	56	Good	Interview & Simulation	Confident

Table 7: Reasons of people who have fear of fall (Marked in yellow are Older adults who are aged 70+)

Handrail usage

There are several variations of stair climbing patterns, one of which is the use of the handrail. A handrail is a multipurpose tool that provides both physical and psychological support that may prevent falls after a trip or slip, decrease loads through the lower limb, or simply augment stability while negotiating stairs. Falling down the stairs can lead to serious injuries such as fractures and sprains. Many such injuries can be avoided by simply using handrails.

Though the majority of the users said that they do not use the handrail outright, they feel that the handrail should be present in all staircases regardless of its size just so that they feel secured from falling out. A small survey was done among different age groups and are as follows.

Most kids did not even realise that they did not use the handrails but some felt that the handrails are not made for their size. One has to reach above their head to access the handrail to use them and they also said that they do not feel the need to use them. While the Younger adults recognize the presence of handrails, the majority of them said that they do not feel the need to use them unless they have any lower limb injuries/difficulties.

However, the answers from the Older Adults were completely different. The majority felt that the handrails are utmost important part of a staircase and they felt that the handrails play a major role in ambulation for them. The fear of fall plays a major role in Older adults who uses the handrails frequently.

The methods involve interviews and observing people at random public places.

Total Younger Adults and Kids: 41

I am physically fit and I frequently use handrails - 5 (13%)

I am physically fit and I rarely use handrails - 8 (19%)

I am physically fit and I never use handrails - 28 (68%)

Total number of Older Adults: 29

I am able-bodied and I frequently use handrails - 19 (66%)

I am able-bodied and I rarely use handrails - 7 (24%)

I am able-bodied and I never use handrails – 3 (10%)

Pinch Grip versus Power Grip

Many researchers have examined grip force capabilities of the human hand. Results of this research indicate that the power grip optimizes grip forces in the hand. Round shaped rails with a diameter of about 1.5 inches maximize grip forces for adults, while a diameter of between 1.125 and 1.25 inches maximizes grip forces for children.



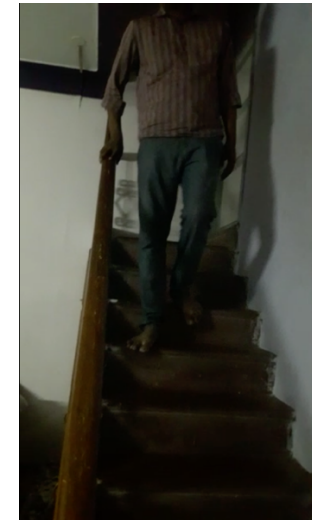
Power grip



Pinch Grip

Figure 18: Types of grips

Rectangular shaped boards tipped on edge produce a nice decorative effect as a handrail and are often easier to attach than round shaped railings. But, as you can see from Figure 4, this type handrail requires a pinch grip, the least effective grip for maximizing the gripping forces in the human hand.



Figures 19-22: Handrail usage of different aged people



Figure 23: Power Grip



Figure 24: Pinch Grip

Age category: Adults						
Sl. No	Name	Gender	Age	Lighting	Do you use handrails?	Comments on Handrails
1	Jarina	F	57	Good	Yes	I'd Like to use circular handrails
2	Hajira	F	64	Good	Yes	I want to use handrails but I don't use it when it looks dirty
3	Malika	F	67	Good	Yes	I want handrails on both the sides of the staircase even if one side of the staircase has wall
4	Fathima	F	65	Moderate	Yes	It should be non Slippery
5	Jamila	F	79	Good	Yes	Its cold on winter months
6	Ismail	M	74	Good	Yes	Steel is getting eroded. Think of someother material
7	Rahamathnisa	F	49	Good	No	Nil
8	Abdul salam	M	80	Good	Yes	Staircase is too wide to hold both the sides
9	Fathima	F	78	Good	Yes	Small enough to hold properly
10	Yousuff	M	71	Moderate	Yes	I like the feel and look of wooden ones. Steel ones tend to get eroded after sometime. I don't like the Stainless steel one.
11	Jaleel	M	51	Moderate	No	Nil
12	Bapat	M	66	Good	No	Flat ones are not so ergonomic to use
13	Mohan	M	56	Good	No	Nil

Table 8: Comments and feedbacks of people who most frequently uses the handrail

Speed of ascend and descend

In order to predict a pedestrian's walking speed on stairs from his/her characteristics of and those of the stairs, the relationship between the walking speed of a pedestrian on stairs and his/her characteristics, and the relationship between the pedestrians' walking speeds on stairs were investigated. Understanding movements of pedestrians is essential to plan and design transport facilities.

Method

Data were drawn from three study groups.

Group 1)

13 healthy subjects, aged between 50 and 81. All of them could walk and ascend/descend stairs in their daily lives without any significant problems.

Group 2)

14 healthy subjects, aged between 23 and 60. They were students and staff at IDC.

Group 3)

11 healthy subjects, aged between 10 and 16. They were kids studying 6th grade to 10th grade.

Each participant was instructed to ascend and descend a staircase as well as to walk on a flat surface, inside the IDC building as well as the staircase that other tests were conducted. The description of the staircase is given below. The final result can be an average of the all the staircase. The staircase consisted of single flight staircase type and had no curves or turns.

At each set of stairs, the participants were asked

- 1) To ascend the stairs at his/her normal speed.
- 2) To descend at his/her normal speed.
- 3) To ascend at his/her fast speed.

Participants could use the handrail and miss stairs according to their preference. All the participants were made to rest properly before taking the experiment so that tiredness does not affect the test. The time taken to ascend/descend the stairs was measured by a stopwatch to calculate the walking speed.

Stair No	Number of steps	Proportion		Total length		Availability of handrail
		Riser height	Tread Length	Horizontal length	Vertical Length	
Stair 1	12	185 mm	230 mm	2.7 m	2.2 m	Yes
Stair 2	12	175 mm	250 mm	3.0 m	2.1 m	Yes
Stair 3	15	150 mm	260 mm	4.0 m	2.3 m	Yes
Stair 4	10	150 mm	320 mm	3.0 m	1.4 m	Yes

Table 9: Staircases used for experiment

Participant List								
Age category: Kids								
Sl. No	Name	Gender	Age	Stair	Ascend speed	Descend speed	Ascend speed	Descend speed
					Normal	Normal	Fast	Fast
1	Sohail	M	10	1	7.1	5.8	5.6	4.1
2	Muhammed	M	12	1	7.3	5.6	5.8	3.9
3	Zeena	F	11	1	7.7	6.1	5.9	4.9
4	Ziad	M	14	1	6.9	5.3	5.3	4.2
5	Reshma	F	13	1	6.1	5.8	5.2	4.4
6	Adil	M	10	1	7.1	5.6	5.9	4.9
7	Shafath	M	14	1	6.8	5.8	5.1	5.1
8	Joudath	M	12	1	7.2	5.9	5.6	4.8
9	Zumana	F	16	1	6.8	5.2	6.1	4.7
10	Humaira	F	11	1	7.7	6.2	6.1	4.9
11	Jasra	F	13	1	6.5	5.8	5.8	4.1
Average			Oct-15		7	5.7	5.6	4.5

Table 10: Climbing speed data of kids

Participant List								
Age category: Adults								
Sl. No	Name	Gender	Age	Stair	Ascend speed	Descend speed	Ascend speed	Descend speed
					Normal	Normal	Fast	Fast
1	Abijit	M	27	4	7.5	6.2	3.3	2.2
2	Ankur	M	26	4	6	6.2	2.5	2.8
3	Negi	M	25	4	6.7	6	3.3	3.9
4	Deepak	M	25	3	4.2	4.1	3.1	2.5
5	Dinesh	M	24	3	5.1	4.9	4.7	2.7
6	Pooja	F	23	4	5.8	4.6	2.7	2.6
7	Kumaran	M	23	3	6.1	5.4	5.3	3.1
8	Gautam	M	25	3	6.2	4.1	5.4	2.9
9	Naveen	M	24	3	7.1	4.8	4.8	3.4
10	Devika	F	23	3	6.8	5.1	4.6	3.7
11	Shankar	M	26	3	5.7	5.9	4.3	4.1
12	Dinesh Raj	M	27	3	7	6.1	5.7	4.9
13	Vignesh	M	28	3	6.8	5.9	4	3.2
14	Irshath	M	23	4	6.3	2.7	5.5	2.1
Average			20-30		6.2	5.1	4.2	3.1

Table 11: Climbing speed data of Younger adults

Participant List								
Age category: Adults								
Sl. No	Name	Gender	Age	Stair	Ascend speed	Descend speed	Ascend speed	Descend speed
					Normal	Normal	Fast	Fast
1	Jarina	F	57	2	7.3	6.7	6.7	5.9
2	Hajira	F	64	2	16.6	15.1	15	14.2
3	Malika	F	67	2	12.2	7.1	11.5	6.9
4	Fathima	F	65	2	17.2	16.3	14.5	13.7
5	Jamila	F	79	2	36.3	28.4	30.1	23.7
6	Ismail	M	74	2	17.9	21.2	12.2	13.7
7	Rahamathnisa	F	49	2	7.3	6.6	5.5	4.9
8	Abdul salam	M	80	2	40	31	36	29
9	Fathima	F	78	2	38.1	29.7	35.5	25.3
10	Yousuff	M	71	2	15.2	9.8	13.4	12.9
11	Jaleel	M	51	2	7.4	6.7	5.2	4.8
12	Bapat	M	66	4	11	6.5	10	6
13	Mohan	M	56	4	6.7	6.4	5.1	3.9
Average			50-80		18	14.7	15.4	12.6

Table 12: Climbing speed data of Older Adults

General Discussions and surveys

Going up and down the stairs questionnaire answers

Total of 29 Older adults (70+)

I go up the stairs but it takes longer:

Yes - 21(72%); No – 8(28%)

I go up the stairs but in a different way. Ex. Step by Step:

Yes - 20;(69%) No – 9(31%)

I go up the stairs but with some difficulties:

Yes – 18(62%); No – 11(38%)

I go up the stairs and almost always use Handrail:

Yes – 27(93%); No -2(7%)

I go up the stairs and I'm almost always helped by someone:

Yes – 3(10%); No – 26(90%)

I go down the stairs but it takes longer:

Yes – 12(41%); No – 17(59%)

I go down the stairs but in a different way. Ex. Step by Step:

Yes – 18(62%); No – 11(38%)

I go down the stairs but with some difficulties:

Yes – 14(48%); No – 15(52%)

I go down the stairs and almost always use handrail:

Yes – 27(93%); No – 2(7%)

I go down the stairs and I'm almost always helped by someone:

Yes – 2(7%); No – 27(93%)

Total of 31 Younger adults

I go up the stairs but it takes longer:

Yes – 2(6%); No – 29(94%)

I go up the stairs but in a different way. Ex. Step by Step:

Yes –0(0%); No – 31(100%)

I go up the stairs but with some difficulties:

Yes –4(13%); No – 27(87%)

I go up the stairs and almost always use Handrail:

Yes – 6(19%); No – 25(81%)

I go up the stairs and I'm almost always helped by someone:

Yes – 0(0%); No – 31(100%)

I go down the stairs but it takes longer:

Yes – 0(0%); No – 31(100%)

I go down the stairs but in a different way. Ex. Step by Step:

Yes –0(0%); No – 31(100%)

I go down the stairs but with some difficulties:

Yes – 2(6%); No – 29(94%)

I go down the stairs and almost always use handrail:

Yes – 3(10%); No – 28(90%)

I go down the stairs and I'm almost always helped by someone:

Yes – 0(0%); No – 31(100%)

Comments and feedback from the participants and common people

1. Visually distracting patterns on the treads should be avoided as they cause confusion and illusion.
2. Lighting at staircase should be properly taken care of.
3. Low-intensity night lighting of stairs that does not need to be switched on should be used.
4. Handrails on each side of the stairway should be provided.
5. Slip-resistant, rough finish on treads that are subject to wetting should be used.
6. Repair or replace tread surfaces every year.
7. Handrails should be provided regardless of the number of steps.
8. Existing handrails that are decorative but not functional should be replaced by functional handrails.
9. The handrails should be easy to see, even in low light or at night.
10. Handrail that is a different colour than the background wall should be designed.
11. Distracting visuals when using a stairway should be avoided.
12. Bathrooms should be on both the floors to minimize stair usage.
13. Clean the stairs and handrails periodically.
14. All the stairs should be even sized.
15. All the staircase should be of same colour.
16. Edges of the steps should be clearly visible and should not merge with the background.
17. No other things should block the vision while using the staircase. The entire staircase should be visible while ascending as well as descending.
18. Handrails should be on reachable level without bending.

Gaze while ascending and descending

Stair walking is a challenging loco-motor task, and visual information about the steps is considered critical to safely walk up and down. Despite the importance of such visual inputs, there remains relatively little information on where gaze is directed during stair walking. Healthy young people walked up and down a set of stairs with 10-15 steps and their gaze is visually noted.

Method: Participants were not only closely observed real time time but also interviewed and some participants' videos were analysed to fully understand the gaze.

As participants approached the stairs their gaze was initially on the starting stair and when they started walked on the stairs, gaze was within 4-5 steps was ahead of their spot. The handrail was rarely the target of gaze fixation.

While the younger people subconsciously know where they are placing their foot and how they are keeping their foot, the older adults kept looking at their feet constantly throughout the ambulation. They tend to make sure whether their foot is properly secured with the necessary clearances front and behind.

Similarly, while descending the older adults tend to follow the same pattern, while the younger adults and kids take only a glance of the starting and the ending stairs. Colour seems to make a huge role in

the ambulation. Also the Riser length need to be same throughout the staircase. People tend to slip more often when its not regardless of the age group.



Figure 25: Older people tend to look at the stairs almost all the time

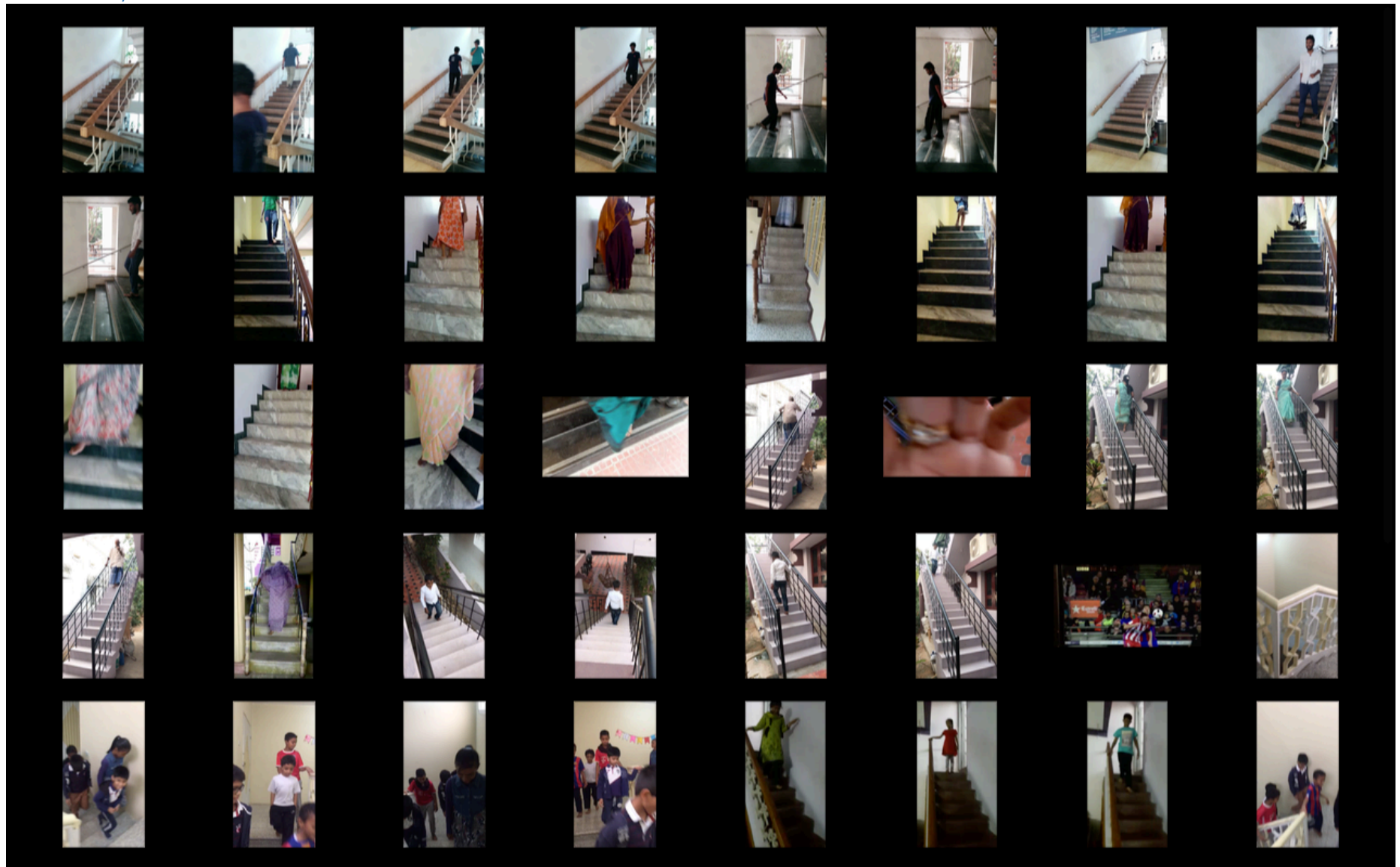


Figure 26: younger people less frequently look at stairs



Figure 27: Older people tend to look at the stairs almost all the time

Video Analysis



Observations at public stairways



Conclusions and Discussions

User preference of staircase elevator: Objective of this survey is to try and compare how people prefer stairs and elevator when the lift and the elevator are organised in a different way. For example in IDC the lift is hidden from the entrance and it is kept in a distance from the staircase. Contrasting the elevator is kept adjacent to the stairs at the main building. This was an observation/comparison between the two to see how people's mind work when the organisation mentioned above are different from each other. People at IDC tend to use staircase more than the people at the main building. The organisation might be a good reason for the result. Or it may just be a coincidence that the people at IDC use the staircase more often. If more work is done on this subject we may find ways to make the spaces organised in a way where the elevator is used less frequently compared to the staircase.

Where do people look for a staircase in a typical public building: This survey would reveal us where would be the right place to plan the staircase. The results from this survey suggested that most of the people when entered into a new building look for a staircase either just outside the entrance or just inside the entrance. The results suggest that is one wants the people to find the staircase quickly can organise the staircase just next to the entrance. While if a person doesn't want the public to find the staircase can organise the staircase at a hidden place or away from the entrance.

Gait Cycle: These observations show the time taken for each phase of climbing for each age category. This can be a can be a base while studying, researching or designing on mobility aids for the age group

to compare and see the overall performance. The reasons for each age category to take the time that they took may be because of several reasons. Age factor, body pain, balance impairment and so on.

Stair ambulation pattern and fear of fall: Two ambulation patterns were found while studying the different types of patterns. The elderly over the age of 75 implemented the SBS pattern while the young people implemented the SOS pattern. The reasons and the process of different patterns were discussed in this observation. The reasons for fear of fall and who were affected by the same were studied and discussed in this survey and observation.

Handrail Usage: The handrails were majorly used by the older adults due to several reasons. Providing handrails for stair use is no guarantee that they will be used. In a survey about 60% of the ascending and descending people overall did not use the handrail at all. About 7% used minimally and only about 16% used it more extensively. The 16% consisted mostly of older adults. There was some indication that handrail use correlates with increasing age and that women use the handrails than men do. Places where there are older adults should have handrails strictly on both the sides and should be cylindrical rather than a rectangular one. Other comments on handrails were discussed in this observation.

Speed of ascend and descend: The speed of all the age group were identified and were quantified. This observation/information could be used as a data base for egress designs.

Gaze: Gaze of all the age group were observed and studied. The study suggest that the gaze of the older people are always on where they are climbing while the younger adults are rarely on the stairs. Most younger adults tend to look at the beginning few steps and the last few steps. Special indications and lighting patterns to the first and last steps may be?

Power generation when climbing stairs?

Materials

Stairs, Tape measure, Scale, Stopwatch or watch that measures seconds.

Method

1. Measure the vertical height of the set of stairs (or a portion that's easily measured), in metres (m). The vertical height refers to the height from the bottom to the top (straight down), not the slope.
2. Determine your body mass, in kilograms (kg) by getting on the scale.
3. Time the number of seconds (s) it takes you to run up the stairs.
4. The amount of power used is equal to the amount of work done over a given amount of time ($P = W/t$). To determine the amount of work done, you calculate the amount of force that is exerted over a given distance ($W = f \cdot d$). The force in this case is calculated by multiplying the downward acceleration due to gravity (9.81 m/s^2) by your mass (in kg)
5. Breaking it down, you get:
Power = Work/time
Power = (acceleration due to gravity) x mass x distance/time

Power = $9.81 \text{ m/s}^2 \times \text{kg} \times \text{m} / \text{s}$ or 9.81 Watts

(NOTE: The unit for power is the Watt, which is $\text{kg} \cdot \text{m}^2 / \text{s}^3$)

6. **Example:** Calculating the power generated by a 54 kg person who takes 5 seconds to run up a 3 metres high set of stairs.

$$\begin{aligned}\text{Power} &= [g (9.81 \text{ m/s}^2) \cdot \text{mass (kg)} \cdot \text{vertical height (m)}] / \text{time(s)} = \\ &\text{watts} \\ &= (9.81 \text{ m/s}^2 \cdot 54\text{kg} \cdot 3\text{m}) / 5\text{s} \\ &= 318 \text{ W}\end{aligned}$$

Average weight of kids of about 12 years old is about 30kg and 60kg for younger adults and about 70kg for Older adults.

Power generated on average for kids – 180 W; Younger Adults – 350 W; Older Adults – 410 W.

What's happening?

Most people associate power with muscles and muscle strength - the larger the muscles, the greater the power. This is only partially true. Smaller muscles that are properly toned can generate larger amounts of power than larger muscles that are not properly toned. This is why athletes that appear small may still be capable of great feats of strength and stamina. Power is the rate at which work is done. The greater the power, the more work that is being done. In sports, the more power that the athlete can generate, the faster, farther, higher, etc., the athlete can go. Ultimately, the amount of power the athlete can generate goes back to how, and how much, the athlete trains and prepares for that particular sport.

How to Properly climb a staircase

One may feel too heavy to climb stairs, or too unfit when confronted with a tall staircase, but it is not actually an issue of size, though it may be one of fitness and function. We have a tendency to think that if we were lighter, things would be easier – but relative weakness and joint dysfunction can occur at any weight.

If we think about stair-climbing, it is remarkably common for us humans to just pitch the torso forwards at the hips, shortening the hip flexors, and after placing our foot on the next step, we basically extend the knee to press our body onwards and upwards. When we usually climb the hip joint moves very little, and so it becomes a *knee-dominant* movement pattern. Relative to the hip, the knee is a very small joint, and if you can imagine practicing a one legged, full bodyweight knee extension – it's actually a very difficult and problematic exercise, even if your thigh muscles are strong.

Also, when we are leaning forward, force from the interaction between our thigh and the ground drives up into the lower back, as opposed to dissipating through the body. Climbing stairs in this way can lead to excessive pressure in the knees and lower back, which can manifest as pain.

If, however, you climb stairs with a *hip-dominant* movement pattern, you bear the weight of the body through two joints, and the primary mover becomes the large and muscular hip joint, as opposed to the relatively unstable knee joint.

So – to reduce stress and pain in the knee, the best way to climb stairs is this – keep your body upright, try not to lean forward, place your entire foot on the next step, apply force through the heel, and focus on pulling your heel backwards *behind your body* as you straighten your leg to move your body up the staircase.

Focusing on driving the heel down also helps to engage the buttocks. As you do so, set your intention to extend the hip *before* extending the knee, if you can. In reality, the joints move almost simultaneously, but focusing more on the hip will take pressure away from the knee.

If you can, hold onto the hand-rail. Another dynamic that keeps us leaning forwards while climbing stairs is the fear of falling backwards. **Do not allow yourself to fall backwards down a staircase!** Be patient, and as safe as you can.

As you fatigue, as the muscles of the buttocks fatigue, the old movement pattern will start to re-emerge. Which is totally okay, this is simply what happens when muscles get fatigued - you automatically rely on other muscles. This is why we train - to build up strength, power and endurance over time, so that we can become *better at moving*.

References:

Staircase

<https://en.wikipedia.org/wiki/Stairs>

Referred on: Friday 2nd December 2016

Components of a typical staircase

[https://en.wikipedia.org/wiki/Stairs#Components and terms](https://en.wikipedia.org/wiki/Stairs#Components_and_terms),

Referred on: Friday 2nd December 2016

what is staircase climbing

<http://www.birmingham.ac.uk/schools/sport-exercise/research/showcase/stair-climbing-to-increase-lifestyle-physical-activity.aspx>,

Referred on: Friday 2nd December 2016

steps

<https://en.wikipedia.org/wiki/Stairs#Step>

Referred on: Friday 2nd December 2016

Where do I start?

<http://www.stairplan.com/wheredoistart.htm>

Referred on: Friday 2nd December 2016

The Ups and Downs of Staircase Design

<https://www.boardandvellum.com/blog/the-ups-and-downs-of-staircase-design/>

Referred on: Friday 2nd December 2016

Move the staircase for better circulation and storage

http://www.builderonline.com/design/move-the-staircase-for-better-circulation-and-storage_o

Referred on: Friday 2nd December 2016

Muscles Used While Walking Up Stairs

<http://livehealthy.chron.com/muscles-used-walking-up-stairs-7534.html>

Referred on: Tuesday 27th December 2016

Evidence and guidance

<https://www.stepjockey.com/evidence-and-guidance>

Referred on: Tuesday 27th December 2016

The complete book of stair climbing

https://books.google.co.in/books?id=HLOYAwAAQBAJ&pg=PA308&lpg=PA308&dq=staircase+climbing+survey&source=bl&ots=cmn2rsHUqG&sig=VQ6LMDJg2BgV1pUY2ukiUCdDgv0&hl=en&sa=X&ved=0ahUKEwjGm9PMs_fSAhXKuI8KHSoZARUQ6AEIMzAD#v=onepage&q&f=false

Referred on: Tuesday 27th December 2016

how to climb the stairs

<http://www.moveandbefree.com/blog/how-to-climb-the-stairs>

Referred on: Tuesday 27th December 2016

Stair gait classification from kinematic sensors

<http://www.diva-portal.org/smash/get/diva2:239015/ATTACHMENT01>

Referred on: Wednesday 18th January 2017

Analysis of lower limb”

https://qspace.library.queensu.ca/bitstream/handle/1974/6092/Reid_Samantha_M_201009_PhD.pdf?sequence=1&isAllowed=y

Referred on: Wednesday 18th January 2017

Basic Building Planning Principles

<https://www.gsa.gov/portal/content/101214>

Referred on: Wednesday 18th January 2017

Stair Safety: Causes and Prevention of Residential Stair Injuries

<http://www.human.cornell.edu/dea/outreach/upload/Stair-Safety-2-2.pdf>

Referred on: Wednesday 18th January 2017

staircase Statistics

<http://senseis.xmp.net/?StaircaseStatistics>

Referred on: Wednesday 18th January 2017

Telemetering electromyography of muscles used in walking up and down stairs

<http://www.boneandjoint.org.uk/content/jbjsbr/49-B/4/774.full.pdf>

Referred on: Monday 23rd January 2017

Muscle Activation Patterns During Level Walking and Stair Ambulation

<http://cdn.intechweb.org/pdfs/25822.pdf>

Referred on: Monday 23rd January 2017

Recommendations for promoting stair use in the Dalhousie Tupper Building

[https://www.dal.ca/content/dam/dalhousie/pdf/science/environmental-science-](https://www.dal.ca/content/dam/dalhousie/pdf/science/environmental-science-program/ENVS%203502%20projects/2012/TakingtheStairs.pdf)

[program/ENVS%203502%20projects/2012/TakingtheStairs.pdf](https://www.dal.ca/content/dam/dalhousie/pdf/science/environmental-science-program/ENVS%203502%20projects/2012/TakingtheStairs.pdf)

Referred on: Monday 23rd January 2017

Different patterns of handrail use at junctions

<https://www.jniosh.go.jp/en/publication/doc/ICFPP27.pdf>

Referred on: Monday 23rd January 2017

Stairs or Escalator? Using Theories of Persuasion and Motivation to Facilitate Healthy Decision Making

<http://people.socsci.tau.ac.il/mu/galsheppes/files/2014/10/2014-7.pdf>

Referred on: Monday 23rd January 2017

Changing Behaviours: On the Rise of the Psychological State

<https://books.google.co.in/books?id=lrvPmQYSCNAC&pg=PA81&lp g=PA81&dq=staircase+and+people+behaviour&source=bl&ots=m3 6TlfvaVe&sig=2y4zFJ7-5xR5wlhtdR1-s3nuuhl&hl=en&sa=X&ved=0ahUKEwjV3fm6hIPSAhXlr48KHeF0D8 QQ6AEISDAK#v=onepage&q=staircase%20and%20people%20behav iour&f=false>

Referred on: Thursday 16th February 2017

Promoting stair climbing: effects of message specificity and validation

<https://academic.oup.com/her/article/22/1/49/579234/Promoting -stair-climbing-effects-of-message>

Referred on: Thursday 16th February 2017

Boosting Workplace Stair Utilization: A Study of Incremental Reinforcement

<http://www.chiprewards.com/wp-content/uploads/2013/04/stairs- paper.pdf>

Referred on: Thursday 16th February 2017

How and when infants learn to climb stairs

<https://psych.nyu.edu/adolph/publications/2007Berger%20S%20E %20Theuring%20C%20%20Adolph%20K%20E- How%20and%20when%20infants%20learn%20to%20climb%20stair s.pdf>

Referred on: Thursday 16th February 2017

Changing affordances in stair climbing: the perception of maximum climbability in young and older adults.

<https://www.ncbi.nlm.nih.gov/pubmed/1500869>

Referred on: Thursday 16th February 2017

The Energy Expenditure of Stair Climbing One Step and Two Steps at a Time: Estimations from Measures of Heart Rate

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3520986/>

Referred on: Tuesday 28th February 2017

Take the Stairs: Stair climbing to increase lifestyle physical activity

<http://www.birmingham.ac.uk/schools/sport- exercise/research/showcase/stair-climbing-to-increase-lifestyle- physical-activity.aspx>

Referred on: Tuesday 28th February 2017

Problems for Elderly People Climbing Stairs

<http://agingparentsauthority.com/elderly-needs/problems-for- elderly-people-climbing-stairs/>

Referred on: Tuesday 28th February 2017

What Does Stair Climbing Do for Your Body?

<http://www.livestrong.com/article/464931-what-does-stair- climbing-do-for-your-body/>

Referred on: Thursday 9th March 2017

Safe stair climbing with a cane

<http://www.hamiltonhealthsciences.ca/documents/Patient%20Edu cation/SafeStairClimbingCane-th.pdf>

Referred on: Thursday 9th March 2017

Study of stair-climbing assistive mechanisms for the disabled

<http://murraylawn.org/mjlneww/StaiCPhD.pdf>

Referred on: Thursday 9th March 2017

Preventing Falls on Stairs

<https://www.cmhc-schl.gc.ca/odpub/pdf/63637.pdf>

Referred on: Thursday 9th March 2017

Ultimate strength-and-cardio workout: stair climbing

<http://healthandstyle.com/fitness/stair-climbing-workout/>

Referred on: Saturday 11th March 2017

How to Climb Stairs to Minimize Knee Strain

<http://www.livestrong.com/article/546772-how-to-climb-stairs-to-minimize-knee-strain/>

Referred on: Saturday 11th March 2017

Staircase glossary

<https://www.wonkeedonkeerichardburbidge.co.uk/staircase-glossary/>

Referred on: Saturday 11th March 2017

The Proper Posture When Climbing Down the Stairs

<http://www.livestrong.com/article/333409-the-proper-posture-when-climbing-down-the-stairs/>

Referred on: Saturday 11th March 2017

Staircase Railings & Child Safety

<http://www.livestrong.com/article/1003464-staircase-railings-child-safety/>

Referred on: Tuesday 14th March 2017

How do the Elderly negotiate stairs?

[http://onlinelibrary.wiley.com/doi/10.1002/\(SICI\)1097-4598\(1997\)5+%3C52::AID-MUS13%3E3.0.CO;2-0/epdf](http://onlinelibrary.wiley.com/doi/10.1002/(SICI)1097-4598(1997)5+%3C52::AID-MUS13%3E3.0.CO;2-0/epdf)

Referred on: Tuesday 14th March 2017

Stairs or Lifts? - A Study of Human Factors associated with Lift/Elevator usage during Evacuations using an online Survey

https://fseg.gre.ac.uk/fire/fseg_ped2010_liftstairchoice_paper_distribution_final_final.pdf

Referred on: Tuesday 14th March 2017

Image source:

Cover page:

http://wallpaperswide.com/climbing_stairs_quickly-wallpapers.html

Figure 1:

<http://www.wapitout.com/images/staircase-anatomy-5-staircase-components-1213-x-1388.jpg>

Figure 2:

<https://smartinsoledotnet.files.wordpress.com/2016/01/phases-of-human-gait-cycle.jpg?w=1400>

Figure 3:

<https://martinsoledotnet.files.wordpress.com/2016/13/phases-of-human-gait-cycle.jpg?w=1400>

Figure 12:

<http://lrmagazine.com/wp-content/uploads/2010/10/10stairs-Figure1-copy.jpg>

Figure 13:

<http://lrmagazine.com/wp-content/uploads/2010/10/10stairs-Figure1-copy.jpg>

Figure 14:

<https://image.slidesharecdn.com/presentation1-140409120209-phpapp02/95/biomechanics-of-stair-climbing-14-638.jpg?cb=1397045718>

<https://image.slidesharecdn.com/presentation1-140409120209-phpapp02/95/biomechanics-of-stair-climbing-13-638.jpg?cb=1397045718>

Figure 18:

<https://promenaid.com/sites/default27/files/pinch.png>

