EVALUTION OF LOAD LIFTING CAPACITY OF FEMALE WORKER IN CONSTRUCTION WORK BY USING A FUZZY LOGIC APPROACH

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ABSTRACT - Work-related musculoskeletal injuries are often associated with overexertion of the body at construction work. The manual material handling activity of lifting is a major source of work related musculoskeletal disorders. Low back disorders (LBD) are most vital problem of female workers who work at construction site and in industry. This problem associated with high costs to the individual and can influence the quality of work and health of female workers. In this paper, researcher work to evaluate load lifting capacity of female worker which play an important role to mitigate lower back ach problem of female worker. In manual material handling, Researcher used the fuzzy logic approach for the same.

KEYWORDS- Manual Material Handling (MMH), Load Lifting, Fuzzy Logic, low back disorders, Female workers.

I. INTRODUCTION

Manual material handling (MMH), especially lifting, represents a major occupational safety and health risk in construction industry. Musculoskeletal and low back disorders are often attributed to overexertion of the body and disabilities associated with MMH tasks, among which LBDs represent the most common and most costly musculoskeletal disorder experienced in the workplace. There are kinds of injuries and ergonomic principles in the design and evaluation of human work has been advocated and promoted in the work place to minimize the occurrence of work related musculoskeletal injuries. The Factory Act, 1948, does not indicate the safe load limit for Indian population. In Maharashtra (one of the developing state in India) the Maharashtra Factory Act (Rules no. 66) specified the maximum limit of weight handled by an adult female worker as 30 kg which seems to be heavy for the workers. According to Joshi et al. (2001), the existing Indian Factory rule inadvertently created the occupational health hazard conditions in industries. Now researchers are going to find the way with age and strength of female worker. In this paper researchers use the fuzzy logic approach for calculating maximum load lifting capacity for each group of female worker for safe handling in construction work.

II. LITERATURE REVIEW

Load Lifting Capacity (LLC) is determined by the workers, as the highest acceptable workload, which can be lifted comfortably based on their perceived exhaustion level (Gamberale, 1985). (Snook, 1978; Legg and Myles, 1981) Use of psychophysical method in determining LLC in repetitive lifting jobs is well established. Snook (1978) first

introduced the term LLC for the industrial workers engaged in different types of repetitive lifting tasks. In his report, Snook proposed a methodology to determine LLC where the subjects are asked to select the maximum acceptable load effectively of their own choice that they can lift under a specific condition for 8-hours workday 'without straining themselves or without becoming unusually tired, overheated, weakened or out of breath'.

In 1981, National Institute for Occupational Safety and Health (NIOSH) recognized the growing problem of work-related back injuries and published a summary of lifting-related literature. It also provided a lifting equation for calculating a recommended weight for specified two-handed, symmetrical lifting tasks, an approach for controlling the hazards of low back injury from manual lifting (NIOSH, 1981). In 1991, NIOSH committee selected this psychophysical criterion as an alternative determinant for estimating the safe load limit. In this criterion, it is mentioned that the estimated load will be accepted by 99% of male workers and 75% of female workers, or 90% of the whole working population (i.e. in a population of equal number of male and females) a revised lifting equation was developed with more number of lifting parameters (Watwers et al., 1993) (Karwowski 1991). In a study on rate of perceived exertion (RPE), showed that while selecting the maximum acceptable weight for 8 hour job, the female subjects rated the load as moderate or heavy weight, whereas most of the male subjects rated the load as either heavy or very heavy. Therefore, the researcher concluded that the female subjects were more realistic with respect to subjective perception of load heaviness in selecting LLC value. Kelsey et al. (1984) also reported similar results.

Mital (1983) reported that at the end of 8 hour, females were lifting only 85% of the load that they had selected at the beginning of the psychophysical experiment. This is because with the advancement of work time, the work efficiency decreases. Several studies (Ayoub et al., 1978; Snook, 1978; Mital, 1984) mention that 20-30 minute experimental work duration is adequate to estimate the appropriate workload for an 8 hour or 12 hour workday. Ayoub and Mital (1989) categorically mentioned that 40-45 minute work period is sufficient to determine the weight, which the subject can lift for 12 hour duration even if it includes 4 hour overtime about which they have no prior warning.

Snook (1978) provided a 40 minute adjustment period to allow the participants to monitor their own feelings and adjust the load weight. Some researchers (Garg and Saxena, 1982; Garg and Beller, 1994) used a longer adjustment period (i.e. 45, 50, or 60 minute). Again, in other studies (Mital, 1983, 1984; Karwowski and Yates, 1986; Mital and Aghazadeh, 1987; Zhu and Zhang 1990; Chen et al., 1992), it is mentioned that participants could determine the LLC load weight within shorter adjustment period. In these studies, the authors identified many factors affecting this perceived subjective response such as, workers and load characteristics, type of task, work environment etc. and also load weight factor. Researchers (Chiuhsiang J.LIN, Shun J.WANG& Hung j.CHEN) suggested the use of ergonomic principles in the design and evaluation of human work has been advocated and promoted in the work place to minimize the occurrence of work related musculoskeletal injuries.

III- FUZZY LOGIC

Fuzzy logic is a powerful problem-solving methodology with many applications in embedded control and information processing. Fuzzy gives a wonderful simple approach to draw definite conclusions from vague information. In a common sense, fuzzy logic resembles human decision making mechanism with its ability to work from approximate data and get accurate solutions. Regarding fuzzy theory as a single theory, the process of "fuzzification" should be regarded as a methodology to generalize any specific theory from a crisp (discrete) to a continuous fuzzy form. Fuzzy are automobiles, autonomous vehicles, chemical process and robotics (T.J. Ross 2004). These successful applications are attributes to the fact that fuzzy system is knowledge based or rule-based system. We have applied this technique to find out the acceptable load for female worker working in Construction Company according to their age and capacity. The flow chart of fuzzy logic is shown in below figure

III - A. ACCEPTABLE LOAD

For evaluating the acceptable load for female worker in the construction site, Researcher takes age and strength as inputs in the fuzzy controller. Then fuzzifying the inputs (developing fuzzy set), applying "if-then" rule and defuzzifying output results. Algorithms have been successfully applied to a variety of industrial application.

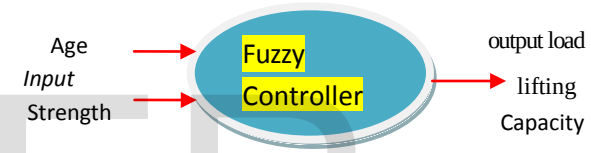


Figure 1: Fuzzy process

III- B. FLOW CHART

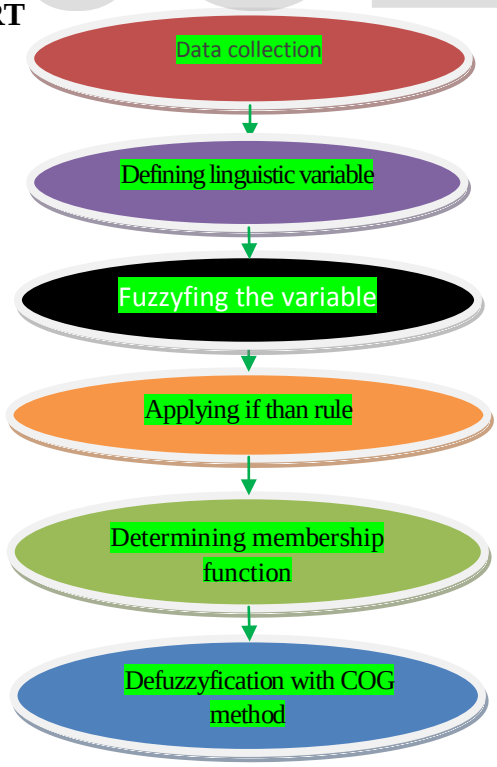


Figure 2: Flow chart of fuggy logic

III -C. LINGUISTIC VARIABLE

Female Worker's age and strength are interpreted as the linguistic variables which have some of linguistics values as follow.

Age: (in years)

(VYA, LYA, YA, LMA, MA, UMA, LE, ME, UE,) [(VYA≤20), (LYA)(15-25), (YA) (20-30), (LMA) (25-35), (MA) (30-40), ((UMA)(35-45), (LE)(40-50), (ME)(45-55),(UE)(≥50)]

Strength: (in kg)

(VL, L, M, H, VH)
[(VL) (<10), (L) (5-15), (M) (10-20), (H) (15-25), (VH) ≥20]

Output load lifting constant:

(VL, L, LM, M, UM, H, VH)
[(VL) (<10), (L)(5-15), (LM)(10-20), (M)(15- 25), (UM) (20-30), (H) (25-35) , (VH) (≥ 35)

III -D. FUZZY SETS

Fuzzy sets are prepared between Female worker age (in yrs) and DOM (degree of membership) which shown in figure 4.1.

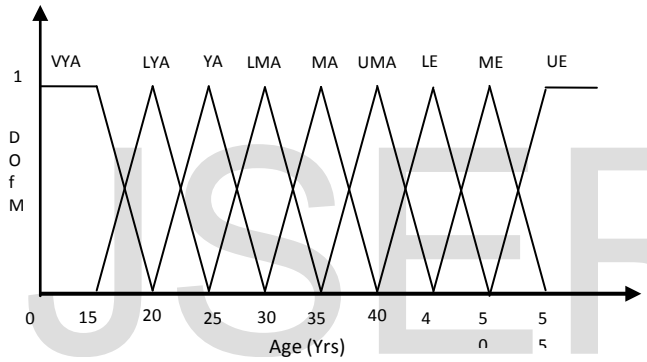


Figure 4.1 for fuzzy set of age

Fuzzy sets are prepared between Female worker Strength (kg) and DOM (degree of membership) which shown in figure 4.2

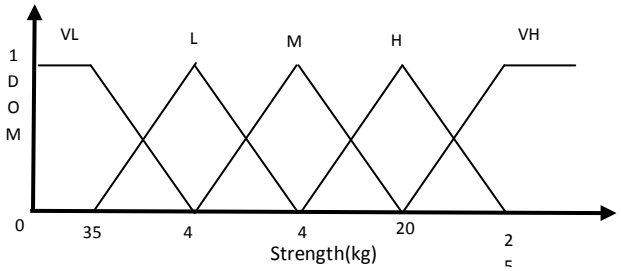


Figure 4.2 for fuzzy set of strength

Fuzzy sets are prepared between Load Lifting Constant (kg) and DOM (degree of membership) which shown in figure 4.3

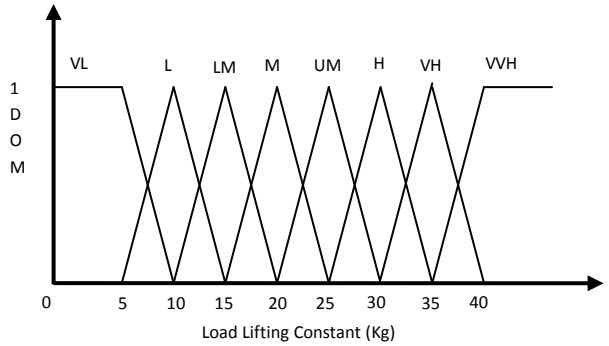
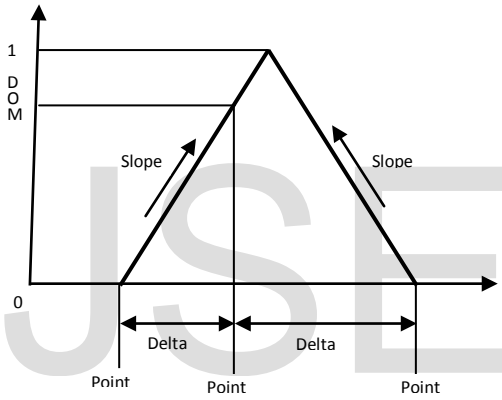


Figure 4.3 for fuzzy set of Lifted load

III- E. FUZZIFICATION OF INPUTS

Following formula is utilized to compute the membership value of antecedents, shown in fig 5.1.



Degree of membership for triangle:

$$\mu(x) = \text{Min}\begin{bmatrix} \text{Delta1} \times \text{Slope1} \\ \text{Delta2} \times \text{Slope2} \\ \text{Max} \end{bmatrix}$$

Where Delta1 = Point X – Point 1 &
Delta2 = Point 2 – Point X
If Delta 1≤ 0 & Delta 2≤ 0
Then Degree of membership = 0

Calculation of Load Constant at medium Capacity:

Let normalized value of age X =20 years then qualifying fuzzy set are shown Fig.5.2

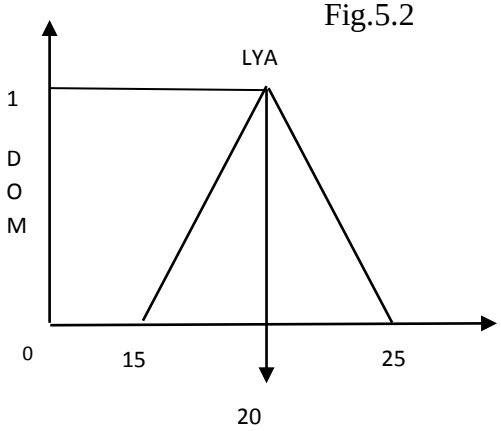


Figure 5.2 for fuzzy set of 20 year age group

Fuzzy membership function of X for LYA
Delta 1 = Point X – Point 1,
Delta 2 = point 2- Point X
Delta 1 = 20 - 15 = 5
Delta 2 = 25 – 20 = 5
Slope 1 = 1/5 = .2
Slope2 = 1/5 = .2

There for degree of membership function for LYA

(X) = Min.

$$\mu(X)_{LYA} = \text{Min.} \begin{pmatrix} 5\times.2 \\ 5\times.2 \\ 1 \end{pmatrix} = 1$$

The Membership function of X with remaining fuzzy sets namely VYA, YA, LMA, MA, UMA, LE, ME, UE is zero (since value of delta 1 & delta 2 is negative)

Similarly let the normalized value of strength be X = 16 kg. Then qualifying fuzzy set is shown Fig. 5.3.

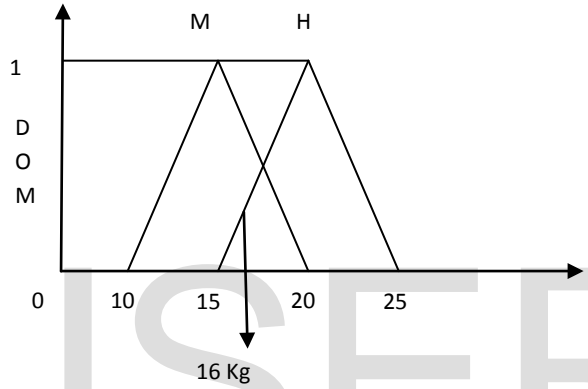


Figure 5.3 for fuzzy set of medium & Higher strength

Fuzzy membership function of X for M
Delta 1 = 16 – 10 = 6,
Delta 2 = 20 – 16 = 4
Slope 1 = 1/5 = .2,
Slope 2 = 1/5 = .2
There for degree of membership function for M

(X) =Min

$$\mu(X)_{m} = \text{Min} \begin{pmatrix} 6\times.2 \\ 4\times.2 \\ 1 \end{pmatrix} = .8$$

Fuzzy membership function of X for H
Delta 1 = 16 – 15 = 1,
Delta 2 = 25 – 16 = 9
Slope 1 = 1/5 = .2,
Slope 2 = 1/5 = .2

There for degree of membership function for H

(X) =Min

$$\mu(X)_{h} = \text{Min} \begin{pmatrix} 1\times.2 \\ 9\times.2 \\ 1 \end{pmatrix} = .2$$

Therefore Membership function of X with remaining fuzzy sets namely VL, L, VH is zero. (Since value of delta 1 & delta 2 is negative)

If than rule –

1. If age is LYA and capacity is L then load const is LM.

2. If age is LYA and capacity is M then load const is M.
3. If age is LYA and capacity is H then load const is UM.
4. If age is LYA and capacity is VL then load const. is L.
5. If age is LYA and capacity is VH then load const is H.

Rule strength computation –

Rule strength is obtained by computing the minimum of the membership function of antecedents.

Rule 1 : Min (1, 0) = 0

Rule 2 : Min (1, .8) = .8

Rule 3 : Min (1, 0) = 0

Rule 4 : Min (1, 0) = 0

Rule 5 : Min (1, .2) = .2

For measured the value of age X = 20 years & medium strength X = 16 kg, the fuzzy membership value for fuzzyfied inputs are shown Fig 5.4.

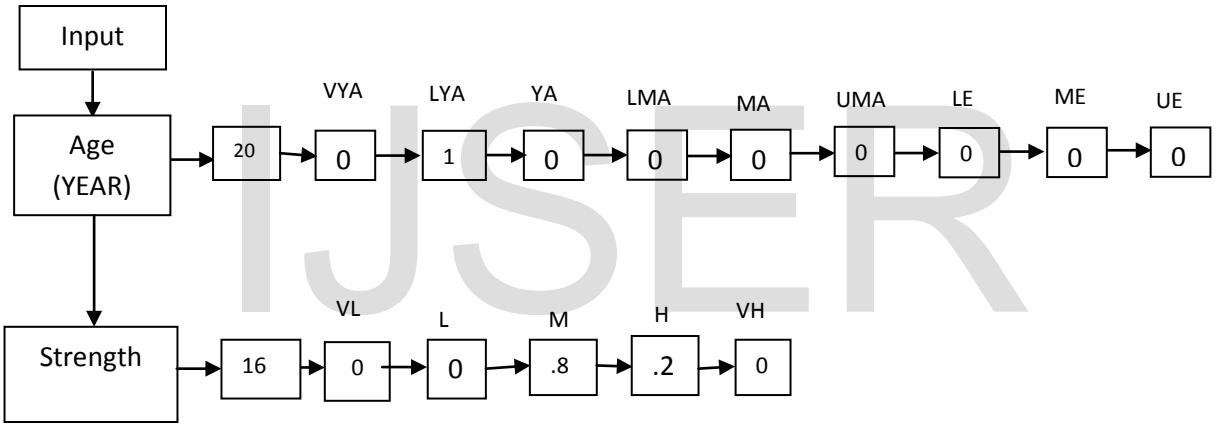


Figure 5.4 for fuzzification of inputs

Defuzzification - Center of gravity method is applied to defuzzifying the output. Fig shows the computation of C.G. for two computing outputs of rule 2 & rule 5 with strength .8, .2. According to rule 2 outputs is medium & according to rule 5 outputs is high.

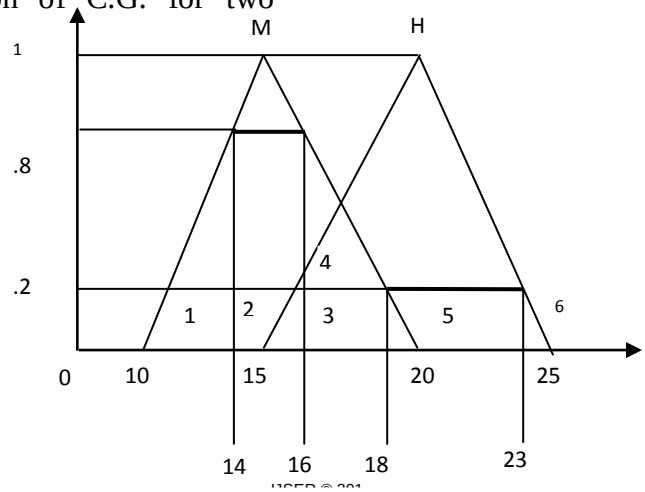


Figure 5.5 for defuzzification

Table shows area and C.G. calculations

S.NO.	Area (A)	Ẍ	AẌ
1.	1/2×4×.8=1.6	12.66	20.26
2.	2×.8=1.6	15	24
3.	2×.2=.4	17	6.8
4.	1/2×2×.6=.6	17.33	10.39
5	5×.2=1.0	20.5	20.5
6.	1/2×2×.2=.2	24.66	4.93
	∑A=5.4	∑AẌ=86.88	

X= ∑AẌ / ∑A =86.88/5.4 =16.08

By similar process load constant is calculated for different age group at different strength, which are shown in below table.

III. Result and Conclusion:

Researcher identifies these parameters and calculates feasible values of load lifting constant. This study was done on adult female construction workers (having age of 18-45 years), who were regularly over-exerted in their working places. From this study, Load lifting constant is estimated around 15 kg. This method will help to estimate the LLC level for variable work duration. This study strongly suggests that the existing factory rule needed to be modified for the welfare of the workers' health.

Table: Load constant for different age group

Strength → / Age ↓	Load Lifting Constant (kg)			
	13kg	**16kg**	**19kg**	**24kg**
20	15.20	16.08	19.38	20.01
25	20.44	17.43	20.57	21.01
30	15.21	16.08	19.38	20.01
35	12.95	16.02	18.38	18.08
40	12.95	15.08	17.57	17.38

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APPENDIX 1

Table 1: Data Collected from the construction side

S.No.	Name of worker	Age (Yrs)	Weight of worker (Kg)	Height of Worker (c.m.)	Lifted weight (kg)
1	Ram kali	28	38	140	9.7
2	Jay shree	24	42	146	9
3	Meena	26	41	147	9.5
4	Anguri	27	41.5	148	9
5	Geeta bai	28	44	151	9.6
6	Aneeta ba.	45	48	160	8.2
7	Sumitra	38	50	145	9
8	Dularin b.	42	54	151	8.9
9	Shanti	18	42	148	13
10	Kamla	45	46	139	9
11	Lakshmi	32	49	144	11
12	Shivani	46	51	153	9
13	Shubhadra	26	49	148	12.2
14	Leela Bati	28	46	147	12.5
15	Ram bati	29	47	147	12
16	Shri devi	18	46	151	13.2
17	Ram sakhi	23	42	152	14
18	Babeeta	21	43	150	12
19	Sarita bai	31	49	148	14
20	Rakhi	30	48	151	12
21	Anjali	28	46	146	11
22	Sangeeta	29	45	152	12.6
23	Puja devi	33	47	151	11
24	Kallo	34	43	150	10
25	Raj kum.	35	48	142	12
26	Puchko b.	31	46	146	9.8
27	Bhutta de.	34	48	151	9
28	Bhuree	26	48	149	10.3
29	Fool bati	24	47	150	12
30	Bitoli	25	43	152	11.2
31	Manno	22	46	146	14
32	Mula	26	51	145	12.8
33	Bekunthi	28	49	147	12.3
34	Guddi bai	24	48	148	13
35	Rani	21	42	146	13.2
36	Chhoti bai	23	48	149	12
37	Kamla	21	40	151	13.3
38	Ramurti	19	42	146	13.4
39	Kishori	20	43	148	9.7
40	Ram shri	18	44	148	12.7

41	Malti	21	49	142	13.7
42	Pushpa	24	47	151	12.8
43	Bina ku.	31	54	149	11
44	Bhuri	28	48	138	11.7
45	Shalu	45	56	139	8
46	Suman	42	51	142	9
47	Uma	38	43	138	8
48	Jai devi	28	45	146	11
49	Gaytri	33	39	136	7
50	Shyam de.	27	45	144	12
51	Surti	18	42	142	13
52	Sushila	22	49	143	14
53	Bejanti	26	44	151	14.5
54	Manju	23	52	153	13
55	Ruchi	25	44	149	14
56	Mohini	19	47	132	15
57	Gopi bai	21	49	132	10
58	Arushi	26	38	135	8
59	Baijanti	24	43	143	17
60	Sunita	34	46	151	16
61	Munnibai	46	43	134	15
62	Ramnathi	43	53	140	14
63	Kamla	34	39	137	12
64	Rukhman	29	41	142	15
65	Kedari	32	44	153	16
66	Dropati	25	38	131	18
67	Leela	23	37	137	11
68	Manju	24	44	139	14
69	Kedari	23	42	136	17
70	Brima	21	47	138	19
71	Guddi	19	40	142	17
72	Jasoda	23	35	137	12
73	Dwarika	33	39	143	17
74	Ram pati	32	41	139	16
75	Sarupi	27	47	145	15
76	Lhori	28	46	142	18
77	Somoti	24	45	153	19
78	Sushila	23	41	155	16
79	Rukhmani	23	43	157	15
80	Hirbo	23	45	138	16
81	Dulari	38	49	159	14
82	Kala	21	54	143	18
83	Bhagvati	32	52	130	19
84	Harheti	20	48	147	24
85	Foolobai	23	43	145	19
86	Leela	18	54	158	23
87	Sarupi	19	47	149	21
88	Janki	18	42	138	22
89	Rambati	19	43	137	21
90	Ramheti	23	45	147	25
91	Chandni	32	43	146	12
92	Kamla	23	46	138	24
93	Papita	29	42	141	20
94	Dhappo	21	48	138	21
95	Tulsi	19	46	153	23
96	Dropati	23	45	139	23
97	Bhuri	26	43	135	22
98	Kailasi	27	47	145	17
99	Gullo	28	43	141	19
100	Barfi bai	27	41	143	21
101	Ramrati	21	47	139	24
102	Tursa	22	39	145	23
103	Kabuli	27	38	137	24
104	Geeta	28	41	148	14
105	Bhagvati	29	47	143	18
106	Sunita	45	48	147	15
107	Leela bai	49	58	148	9
108	Prema ba	29	52	129	13
109	Maya	27	42	132	17
110	Ramheti	23	48	144	24
111	Lalita	32	45	148	23
112	Samanti	28	49	132	21
113	Ramkany	23	48	145	20
114	Dropati	25	42	142	19
115	Bhagvati	27	41	151	23
116	Ganga	18	47	153	25
117	Janki	23	54	145	17
118	Kranti	26	49	142	18
119	Guddi	29	45	138	17
120	Sita	28	39	132	17
121	Badami	24	43	147	21
122	Foolbati	43	54	152	22
123	Bitta	45	52	142	13
124	Rampyari	41	54	145	16
125	Daduya	43	52	147	13
126	Kalyani	32	53	139	15
127	Sarupi	21	51	142	17
128	Chhato	18	48	143	13
129	Gilasi	23	42	142	17
130	Motya	36	57	149	18
131	Kamleshi	32	52	152	19
132	Suaa bai	36	42	142	11
133	Kapuri	23	46	147	10
134	Salin	31	51	143	8
135	Dulli	21	48	139	17
136	Sureshiba	29	42	142	14
137	Samita	34	51	149	15
138	Katlo	38	58	143	12
139	Sawal	42	52	147	17
140	Kaushlya	49	59	142	8
141	Laksho	53	49	146	9
142	Ratni	51	54	149	11
143	Imarati	43	57	142	13
144	Siya bai	53	59	148	9
145	Dhappo	28	45	142	16
146	Shakuntla	24	49	149	14
147	Basanti	36	41	137	11
148	Kusum	27	43	130	19
149	Jyoti	25	49	143	16
150	Meena	29	45	151	19
151	Gaytri	32	39	142	12
152	Rampyari	33	41	139	10
153	Archna	37	44	143	13
154	Narmada	32	49	145	21
155	Sona bai	51	58	152	12
156	Latabai	42	45	149	14
157	Shakuntla	27	44	137	22
158	Lakshmi	23	47	150	16
159	Chunmun	33	48	143	14
160	Kishori	23	46	149	11
161	Ram kali	22	49	143	12
162	Hemvati	28	23	135	16
163	Leela	18	43	134	21
164	Ram bati	19	46	143	22
165	Puspa	21	54	154	19
166	Yasoda	22	45	143	17
167	Prembati	32	54	137	14
168	Bhagbati	33	45	149	11
169	Ramola	32	41	139	16
170	Mamta	23	43	130	12
171	Guddan	27	39	143	11
172	Jamuna	19	47	150	9

173	Chhoti	28	56	148	16
174	Anita	19	51	139	11
175	Janki	32	45	138	15
176	Prema	34	49	140	9
177	Maya	23	43	138	12
178	Parvati	33	43	137	11
179	Meenu	19	52	144	21
180	Pushplata	32	56	138	11

APPENDEX2.

VYA - Very Young Age
LYA - Lower Young Age
YA - Young Age
LMA - Lower Middle Age
MA - Middle Age
UMA - Upper Middle Age
LE - Low Elder
ME - Medium Elder
UE - Upper Elder

H - High
VH - Very High
VL - Very Low
L - Low
LM - Lower Medium
M - Medium
UM - Upper Medium