Mesolithic and Neolithic human remains in the Netherlands: physical anthropological and stable isotope investigations

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Abstract

This article presents an overview of the interdisciplinary study of skeletal remains from Late Mesolithic and Middle Neolithic sites in the Lower Rhine Basin. The combination of archaeological, physical anthropological and chemical analysis has led to a better understanding of the treatment of the dead, demographic parameters and diet of the populations during the transition from forager to farmer in this area. Burial ritual was variable during this whole period, with an above-ground treatment of corpses alongside the burial of deceased. The physical anthropological study has revealed that the sites were inhabited by family groups. Stable isotope analyses have indicated that immigrants were sometimes present and that diet varied per population. Intersite variation in diet is explained by the exploitation of the local habitat. Intrasite variability in diet can be influenced by cultural and social factors as attested by the burial traditions and the isotope study of provenance. It is posited here that the Neolithisation process was not as unambiguous as in some other parts of Europe, but diverse with small-scale variations at the site level.

Keywords: burial traditions, diet, health, Lower Rhine Basin, Mesolithic, Neolithic, demography, physical anthropology, stable isotopes

1 Introduction

The changes in lifestyle during the Mesolithic-Neolithic transition have been studied extensively by many scholars. They address themes like subsistence and settlement strategies, mortuary variability, demographic composition, health, and lately especially migration and diet.

For decades the relation between the health status and living circumstances has been studied and debated (*e.g.* Cohen & Armelagos 1984). Major topics in these discussions are the changes in demography and health brought on by the agricultural transition on a worldwide basis. These studies include ethnographic groups and archaeological populations based on skeletal series. Angel (1975) analysed the skeletal evidence from Eastern Mediterranean populations and pioneer work was performed by Acsádi & Nemeskéri (1970), who established the

mortality profiles of Hungarian groups from the Palaeolithic period onwards.
While the introduction of agriculture holds advantages associated with a sedentary way of life and food production leading to population growth (*e.g.* Bocquet-Appel & Dubouloz 2004), disadvantages existed as well in respect to crop failures, a less variable diet and the spread of all kinds of infectious diseases. An overall view emerged from these studies that anticipated a decline in health with regard to nutritional stress, physical workload, stature and life expectancy for the early Neolithic period (*e.g.* Cohen & Armelagos 1984; Roosevelt 1984; Wittwer-Backofen & Tomo 2008).

An important aspect in the study of past populations has always been the debate on their local origins, large-scale or small-scale migration. The question is of special interest in the debate on the process of 'Neolithisation', the spread of agriculture. For long it was attempted to answer these questions on the basis of artefact typology and/or metrical anthropological evidence, but both approaches appeared to be untenable. The solution to this dilemma has come within reach with the development of isotopic research and its application to archaeological bone material, human as well as animal. The ratio of strontium isotopes especially appeared to be highly significant for geological formations and as such to provide a tool to discriminate between locally grown and non-local individuals. The application to Bandkeramik cemeteries in south-western Germany, especially the analysis of tooth enamel, showed that the communities had a heterogeneous composition. Quite a number of native people from the upland, especially young women, were integrated into the loess-bound Bandkeramik communities (Bentley 2007).

The change in diet, defined by the introduction of domestication and cultivation, is a crucial element in the Neolithisation process. One of the aspects is the consumption of fish, which is supposed to decline throughout the transitional period in favour of terrestrial food sources like domesticated animals and plants. Several trajectories of the Neolithisation process are observed in northwestern Europe. In some areas – like Britain and Denmark – a rapid shift in subsistence is attested (Richards *et al*. 2003a, 2003b). More recent research has revealed however that a sharp shift cannot be observed in the whole of Denmark: both, Mesolithic and Neolithic, populations had a diet with a substantial aquatic component (Fischer *et al*. 2007a, b). In Southern Sweden the coastal populations held onto their own traditions longer and changes in diet were subtle and gradual (Lidén *et al.* 2004). In other areas, Brittany and the Meuse valley, comparisons between Mesolithic and Neolithic sites are difficult and no clear view emerges on the nature of the transition (Schulting 1998; Schulting & Richards 2001; Bocherens *et al*. 2007). Apparently evidence and views differ on the progression in the adoption of new subsistence strategies and changes in diet. This is understandable as the Mesolithic and Neolithic sites are often situated in different ecological settings and cultural traditions concerning the exploitation of the local surroundings may have been of influence on this progress. Comparisons are moreover hindered by the fact that Mesolithic and Neolithic sites often are situated in different (sub)regions. Even if Mesolithic sites were present in the immediate neighbourhood of Neolithic ones, the exploitation of a variety of habitats would result in an isotopic blend of seasonal food sources, with for instance an alternating regime of a more aquatic and a more terrestrial diet during the year.

A series of sites in the wetlands of the Lower Rhine Basin, dating from the Late Mesolithic and Middle Neolithic, have been excavated and produced a considerable number of burials and consequently human skeletal remains. This material offers the opportunity to present a Dutch contribution to the study of these themes. Archaeological, physical anthropological and stable isotope analyses are integrated to investigate these changes in the way of life during the transitional period. An overview of the relevant sites is presented here based on the publications by various scholars. The information on the mortuary variability and physical anthropological data are derived from these publications. New is the application of stable isotope analysis to the research on migration and diet.

An earlier stable isotope study (Smits *et al*. 2008) concentrated on material from the Schipluiden and the Swifterbant sites. This investigation was performed in cooperation with the University of Durham, and enabled us to identify some immigrants in the two Middle Neolithic populations of Swifterbant and Schipluiden. The results of that study will be integrated here. That research has been extended with cooking residues from Schipluiden pottery and samples from human and animal bones from both Hardinxveld sites (Polderweg and De Bruin).

2 Material and methods

Excavations in the Lower Rhine basin have yielded the human skeletal remains of *c.* 150 individuals (table 1). The human bones from the Late Mesolithic and Middle Neolithic sites present a range from more or less complete articulated skeletons, recovered from graves, to single isolated bones scattered in the refuse deposits. Late Mesolithic sites are Polderweg, De Bruin and Mariënberg. Cremated remains are known from this period at Dalfsen and from the Middle Mesolithic period at Oirschot. The early Neolithic period is dated 5300-4300 cal BC in the Netherlands, but agrarian communities (Bandkeramik, Großgartach, Rössen) are restricted to the extreme southern part (South Limburg) in this era. No human skeletal material has been preserved in Bandkeramik cemeteries. Communities in the study area were foragers and, from 5000 cal BC onward, ceramic and on that basis considered to be Early Swifterbant. There are no burials in the study area related to these communities. The Middle Neolithic sites belong to the middle phase of the Swifterbant culture (the Swifterbant sites, Urk and Zoelen) and the Hazendonk group (Schipluiden and Ypenburg). It should be noted that the isolated remains from the phases 2 and 3 (N=10) of the Hardinxveld sites are included in the Late Mesolithic sample. These phases are ceramic (Early Swifterbant) but non-agrarian and should as such be considered as (final) Mesolithic.

phase	site	graves	individuals	dispersed remains	MNI
Late Mesolithic / Swifterbant culture, early phase					
	Hardinxveld-Polderweg	2	2	80	12
	Hardinxveld-De Bruin	2	2	10	7
	Dalfsen			1	1
Swifterbant culure, middle phase					
	S2	9	9	18	27
	S3	0	0	15	14
	S21, 22, 23	13	13	6	17
	S11	2	2	22	2
	Urk	5	8	2	10
	Zoelen	1	3	0	3
Hazendonk group					
	Ypenburg	31	42	8	>42
	Schipluiden	6	7	36	15
	totals	62	86	196	>150

Table 1 Human remains from the Lower Rhine Basin c. 5500-3500 BC. [1]

The site locations are indicated in figure 1. The treatment of the dead is studied in relation to their archaeological context, like grave types and goods, and the nature of the find (complete burials or isolated bones).[2]

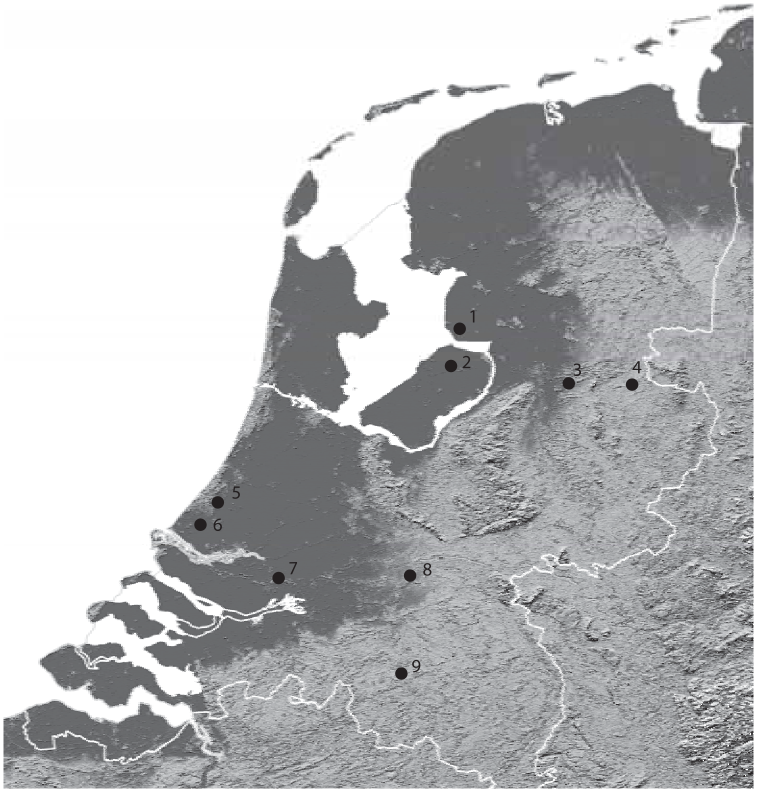

Fig. 1 Location of the Mesolithic and Neolithic sites in the Lower Rhine Basin.

The demographic analysis aims to reconstruct the group composition and thereby to contribute to the functional interpretation of the sites. The basic parameters are based on the physical anthropological publications of the human remains, which comprises age and sex diagnosis. Methods of anthropological age determination represent a biological age, which can only serve as a rough estimate for the real chronological age. Aspects like heath and diet, lifestyle and genetic factors influence the aging process and therefore show a strong individual variety, especially for the adult age groups (*e.g.* Kemkes-Grottenthaler 2002). Therefore the results have to be assessed with caution. Another point in this respect is the fact the physical anthropological investigations were performed by different scholars during a considerable time span and with the application of different methods. The demographic parameters are presented but the analysis of the populations will be mainly based on the percentage of subadults (below the age of 20 years at death) versus adults. The demographic comparison with other Mesolithic and Neolithic populations in Europe will be directed at the proportion of juveniles between 5 and 19 years at death. The age category 0-4 years is excluded because children from this age group are mostly underrepresented in cemetery populations. The proportion 5-19 years is calculated by dividing the number of individuals from 5-19 years with the number of individuals from the age of 5 onwards, **15***P***5** = d(5-19)/d(5+) (Bocqet-Appel & Paz de Miguel Ibánez 2002). This proportion is correlated to fertility, as a high mortality rate means a high birth rate as well, and is therefore used as a means to establish the growth rate of a population.

The demographic data indicate, whether the sites were inhabited by family groups. This aspect focuses on the function of the sites, especially base camps versus specialised extraction camps. Not only is the age at death relevant in this respect, but also the recovery of shed milk teeth, showing that children were living at these locations. They are of no importance however for the mortality profile of the populations.

The topic of health is approached by other aspects of the anthropological study, namely the evaluation of paleopathological phenomena associated with diseases, physical stress, trauma, and the stature of adult individuals. Chronological trends in stature can be related to changes in economy and the associated health of the people (Roede & Van Wieringen 1985; Maat 2005).

Considering the composition of the populations it is interesting to know whether these people were all local or if any outsiders were present. Of course being 'foreign' can be reflected in the variability in the treatment of the dead; aspects like burial type, grave goods of a special (foreign) nature, position of the body, can be taken into account but the interpretation of these traits is not unambiguous and the relevant evidence is restricted in our case. Chemical analysis of bone tissue, especially dental enamel, offers an opportunity to pinpoint immigrants in a population by way of their isotopic make-up and therefore it is desirable to incorporate chemical analysis in the study of mortuary variability and of human skeletal remains in general.

Biochemical analyses of the human bones have been applied to reconstruct aspects of the diet as well. By carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) analyses the composition of the protein part of the diet was investigated (contribution by J. van der Plicht).

3 Background: Mesolithic and Neolithic sites in the Lower Rhine basin (c. 5500-3500 cal BC)

3.1 Late Mesolithic sites

From the Late Mesolithic the most important sites are both sites at Hardinxveld-Giessendam: Polderweg (5450-5050 BC.) and De Bruin (5250-4500 BC, Louwe Kooijmans 2001a, 2001b; Mol & van Zijverden 2007). The sites are located on river dunes that were, at least in their first phase, occupied in winter. Apart from profuse habitation remains, several graves and isolated scattered human bones were recovered, in total representing 19 individuals. At Polderweg one complete and one disturbed grave were excavated. The complete grave held the skeletal remains of an elderly woman, the oldest known skeleton from the Netherlands. She was buried on the back with stretched limbs. Some tiny pieces of red ochre were also recovered from the grave pit as well. At the site of De Bruin one of the graves contained the bones of a man from which an originally sitting position could be deducted. An interesting observation is a healed depression fracture on the right parietal bone of the skull (fig. 2). The size and shape indicates a blunt force trauma with a longitudinal object like a club. A third grave had been disturbed in ancient times leaving only the upper half of the skeleton. It belonged to a man who had been buried in a supine position just like the Polderweg woman. From the graves with the skeletal remains of the male individuals no grave goods were recovered.

The physical anthropological study of the human skeletal remains indicate the presence of men, women and children which show the occupation of both sites by family groups (Smits & Louwe Kooijmans 2001; Louwe Kooijmans & Smits 2001). This finding supports the archaeological evidence concerning the varied toolkit, the long occupation period and the presence of formal burials, which typify these sites as base camps (Louwe Kooijmans 2001a,b).

At Mariënberg an extensive complex of Middle and Late Mesolithic hearth pits was excavated, together with some Beaker burial pits. A group of six Mesolithic pits, indirectly dated to *c.* 5100 cal BC., were interpreted by the excavator as grave pits, in view of the presence of red ochre colouring of the pit fills and some specific objects, especially so-called arrow shaft polishers. The deceased would have been buried in a sitting position (Verlinde 2005; Verlinde & Newell 2006). This interpretation is disputable, mainly because no human remains were preserved (Louwe Kooijmans in press).

Fig. 2 Hardinxveld-De Bruin, burial 2, skull of an adult man with healed depression fracture on the right parietal bone, Late Mesolithic (after Louwe Kooijmans & Smits 2001)

Two sites yielded a few cremated remains in a settlement context; these are Dalfsen (Verlinde 1974) and Oirschot (Arts & Hoogland 1987). The interpretation of the remains at Late Mesolithic Dalfsen is unclear, as only a few calcinated bones were recovered from the fills of some domestic pits. At Oirschot a distinct concentration of cremation remains of one subadult individual, 10-13 years of age, were found, associated with a small pit and a small flint scatter. The complex is dated to the Middle Mesolithic on the basis of microlith typology and several ^{14}C dates, one from the cremated bone itself (GrA-13390 8320 ± 40 BP, Lanting 2001).

3.2 Middle Neolithic sites

The Swifterbant site cluster is eponymous for the Swifterbant-culture, as characterized by specific point-based pottery with wide flaring rims. The cluster comprises several river dunes and river banks on which settlement traces, burials and isolated human bones have been discovered (Van der Waals 1977). Formal burial grounds were located on the sites of S11 and S21-23, dating from the period 4200-4000 BC. Burial practices are comparable with those witnessed at Hardinxveld-Giessendam, indicating that the dead were buried in a supine position without grave goods except for a few amber beads.[3] The study of the human remains of *c.* 66 individuals, based on the burials and the isolated human bonesprovided insight into the population structure with the presence of men, women and children indicating the use of these areas by family groups (Meiklejohn & Constandse-Westermann 1978; Constandse-Westermann & Meiklejohn 1979).

At Zoelen an extraordinary grave was excavated dating from *c.* 4000 cal BC. An association with a nearby settlement is unknown as the excavation was limited to this location. This grave contained the skeletal remains of three individuals, two women and one child. At the bottom of the grave the articulated skeletal remains of a child of *c.* 7 years old at death were discovered. It had been buried face down. Positioned on top of this child were the articulated bones of a woman of *c.* 50-70 years of age, positioned face down as well. Deposited on top, separated by a thin layer of organic remains like plants or leaves, were a few unarticulated bones belonging to another woman of *c.* 30-60 years of age. Apparently this was a burial of a number of skeletonised remains after decomposition of the body (Hogestijn & Lauwerier 1992).

Near Urk a small burial ground from *c.* 4200-3400 cal BC was discovered on the highest part of a dune that was used as a settlement site in the same period, although not necessarily at the same time (Peters & Peeters 2001). Five grave pits were found, which held the skeletal remains of eight individuals. The burial position is variable. Five individuals were buried extended on the back, another may have been buried on the right side in a crouched position, but the interpretation of the incomplete and badly preserved remains is problematical. In addition there was a grave with remains of three individuals. Apart from these burials two isolated skulls – one with articulated mandible – were found that might have been discarded, as no traces of a pit were present. But as the bone tissue was badly preserved it is not improbable that the remainder of the skeletons have decayed altogether and in absence of more precise evidence these skulls might best be interpreted as the last remains of formal burials. The bad preservation conditions could also explain the almost complete absence of the skeletons of young children and infants, which if present originally, will have fully decayed as well. The top of the dune was moreover eroded. Shallow graves may thus have disappeared. The total number of individuals from this site amounts to ten. The sex and age diagnosis indicated the presence of adult men and women and a single bone of a child.

One grave contained five amber beads, which were probably part of a necklace. No other gifts or material items were present.

On a coastal dune at Schipluiden, a settlement has been excavated, dating from *c.* 3600-3400 BC, as well as a small burial ground and scattered human bones. The layout shows that this was a permanent settlement of several cooperating households; the analysis of the archaeozoological and archaeobotanical remains supports a year round occupation (Louwe Kooijmans & Jongste 2006).

The individuals were positioned in the graves with tightly flexed limbs. The position of the trunk showed some variation, on the chest, on the back, on the left or right side. The skeletal remains of seven individuals were discovered in six graves, one of which was a double grave. At least another eight individuals were represented in the scattered bones around the site. The human remains represent mainly adult men and children. Only one isolated bone was identified as being (possibly) from a female individual. The anthropological findings, both from the graves and the scattered bones, indicate the presence of family groups (Smits & Louwe Kooijmans 2006).

Grave goods were almost absent; one child was buried with a few beads made of bird bone and one man originally held a strike-a-light, consisting of several flints and a fragment of pyrite, in his hand.

An extensive Middle Neolithic settlement area with a cemetery, dating from the same period as Schipluiden, has been excavated at Ypenburg (Koot *et al.* 2008). The cemetery could, however, not be associated with any of the seven house sites, nor attributed to one of the occupation phases. Two clusters of graves comprise 31 graves with a total of 41 individuals. Some loose human bones were recovered as well from domestic refuse. Most of the dead were buried with flexed limbs in shallow grave pits. Twelve individuals were deposited on the left side, 8 on the right side, and 5 in a supine position. Only 2 individuals were buried in a stretched posture. Of 14 individuals the exact position is unknown owing to the unarticulated arrangement of the skeletons in these graves, caused by post-depositional disturbances. The population comprised men, women and children indicating the presence of complete households (Baetsen 2008). No relation between burial position, sex and age could be attested. Material items were limited to some personal adornments like beads, associated with 9 individuals, comprising 1 men, 2 women and 6 children.

4 Burial practices

4.1 Inhumation graves

The inhumation graves comprise single, double and multiple burials. Single primary burials were most common. From roughly 5500 until 4000 BC most individuals were buried stretched on the back with extended limbs as was attested at Hardinxveld-Giessendam, Swifterbant and Urk. An exceptional custom was observed in one of the graves at De Bruin, where a man had been buried in a sitting position. That same posture is assumed by the excavator for the presumed grave pits at Mariënberg.

The burial posture had completely changed around 3500 BC, at the Middle Neolithic sites of Schipluiden and Ypenburg, to one in which the arms and legs were tightly flexed, sometimes in an extreme way, which can only be explained by the binding of limbs (fig. 3). Also the range of variability in the position of the torso was similar at both sites.

Fig. 3 Ypenburg, burial 13, a tightly flexed adult female individual, characteristic for the Middle Neolithic Hazendonk Group (after Baetsen 2008).

Multiple graves can represent a single deposition or repeated burials at different time intervals. In the case of a single act the deceased were deposited in the grave simultaneously, indicated by the articulation of the skeletons. Overlapping limb bones can show the sequence of deposition as well. The double grave at Schipluiden has the appearance of a single deposition, since both skeletons were articulated, no disturbance was visible and the overlapping of the bones indicates a simultaneous burial (fig. 4). Reasons for primary double or multiple burials can only be guessed at. There is no association with sex or age, so every grave has to be interpreted on its own. The double grave at Schipluiden for instance contained the skeletons of two men. One of them had a severe injury on the skull indicating a violent death. Although the bones of the second individual reveal no traces of the cause of death the simultaneous character of the burial serves as indirect evidence for a violent death of this man as well, implicating – because they were buried in one act – that they probably died at the same time and from the same cause.

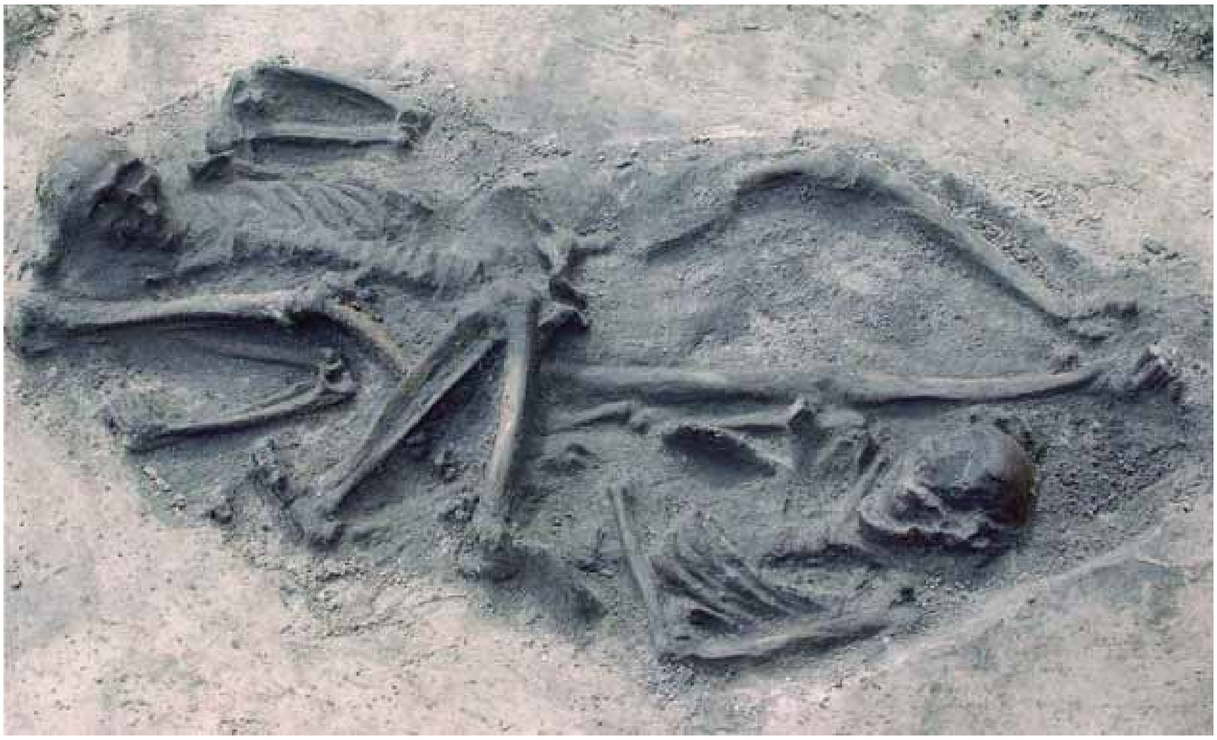

Fig. 4 Schipluiden, burial 1, primary double burial of two adult male individuals, Middle Neolithic Hazendonk Group (after Smits & Louwe Kooijmans 2006).

A primary double burial at Ypenburg contained the skeletons of two children and tells a completely different tale. As these skeletons do not display pathological bone changes, possibly an infectious disease of short duration was responsible for the death of both children at approximately the same time.

Repeated primary burials are characterised by a sequence of depositions separated by time intervals, which probably correlated with the time of death of the individuals. The grave was reopened for an additional deposition of a corpse, thereby disturbing the human remains already in the grave. At Ypenburg some burial pits show inarticulate skeletal remains, which may have resulted from this practice. Most obvious is the deviation of the posture of the buried individuals as compared to single burials, and the absence of grave goods. In Urk one of the graves held the remains of three individuals, which seems to be a repeated burial as well. The grave at Zoelen is exceptional because it seems to be a primary grave in the first instance with a secondary deposition on top of it. The secondary nature of the deposition refers to the phenomenon of the (re)burial of a collection of human skeletal remains that were initially buried or exposed at another location.

Underlying factors for the presence of repeated double and multiple burials could relate to social or cultural traditions, practised by for instance kinship groups or immigrants, with specific rules of their own such as the burial of members in a communal grave.

4.2 Isolated scattered bones

At all settlement sites, with only one exception (Swifterbant S2), loose scattered bones have emerged in variable quantities. They originate from different contexts like cemeteries, occupation layers and refuse zones of the settlements. Post-depositional disturbances of graves were attested at several sites and may have been responsible for part of the dispersed remains, but there are other options that will be considered here. The explanations comprise taphonomic processes, postdepositional disturbances and intentional actions or rituals.

The number of dispersed bones in relation to the minimum number of individuals that they represent shows that only 2.5 % has been recovered, as measured by the number of bone identifications and based on the fact that the skeleton of an adult individual consists of 206 bones. So 97.5 % of the bones disappeared completely. These is not surprising as the human remains ended up above the ground and were open to the elements, to be dispersed by water or wind, eaten by scavengers, or trampled and fragmented by all kinds of activities during the occupation of the sites.

Firstly, the nature and composition of the bone elements can be of importance for assessing the taphonomic aspect. An inventory shows that compact bones, like the cranium, teeth and shafts of the long bones, constitute the majority of the bone spectrum. Skeletal parts that comprise mainly spongy bone tissue, like vertebrae, ribs and the pelvic girdle, only form a small component. Apparently the compact bones have a better survival rate (table 2). On the whole there is no pattern, which distinguishes between the degrees of weathering of the isolated bones in comparison with the formal burials. The preservation of the skeletal remains in the graves can be very bad, on the other hand isolated bones can be very well preserved, especially when incorporated in aquatic clay deposits.

site	cranium	teeth	vertebrae costae scapulae clavicle	pelvic girdle	appen-dicular skeleton	unknown	total no. of dispersed bones	no. of individuals
Hardinxveld-Polderweg	8	32	6	-	29	5	80	10
Hardinxveld-De Bruin	2	2	1	1	4	-	10	3
Swifterbant	7	-	-	-	4	-	>11	6
Urk	2	-	-	-	-	-	2	2
Schipluiden	11	16	1	-	8	-	36	8
Ypenburg	1	5	1	-	2	-	8	2
totals	31	55	9	1	47	5	>147	31

Table 2 Isolated skeletal remains from the Mesolithic and Neolithic sites in the Lower Rhine Basin.

Secondly, human manipulation of skeletal remains can be supported by special traces on the bones, like cut marks. They give rise to various theories, comprising not only cultural traditions concerning mortuary ritual but also acts of violence and cannibalism. Several indications of violence were observed in the material under study. The skull of a man at De Bruin showed a healed depression fracture caused by a blow on the head. In grave 1 at Schipluiden two men were interred, one of which shows a bashed-in skull. The fact that their burial differed from the others may be linked to an exceptional cause of death, probably violence. Considering that injuries to soft tissues are indistinguishable, violent behaviour might have been much more frequent and underrepresented in the osteological record. So we can expect different types of action, concerning violence and violent death of members of the local group or enemy groups, to be reflected in mortuary practices. In the case of warfare, trophy hunting should also be taken into account. The isolated skulls, that were discarded in the refuse zone at Polderweg, may be related to these habits. We can expect the same phenomenon at Schipluiden and Swifterbant. The two skulls from Urk are questionable in this respect as bad preservation prevents interpretation as isolated depositions or the last testimonies of formal burials.

Thirdly, cultural traditions can be responsible for the attested scattered remains as well. The grave at Zoelen for instance shows a secondary interment of an incomplete skeleton. Dismemberment and defleshing can be expected, either with the use of tools or in a natural way, like decomposition elsewhere and possibly above ground. At Hardinxveld-Polderweg a clavicle was found with repeated identical cut marks on it, caused by a sharp-bladed flint tool. These cutmarks were identified as perimortem – inflicted at or around the time of death – and may even be associated with cannibalism (fig. 5). A similar find at a Neolithic chambered tomb at West Tump in the United Kingdom is interpreted as an instance of decapitation (Smith & Brickley 2004).

Fig. 5 Hardinxveld-Polderweg, isolated human clavicle with cutmarks, Late Mesolithic (after Smits & Louwe Kooijmans 2001).

Cannibalism may leave some traces on the bones. One is the fracturing of the long bones and skulls to extract marrow and brain tissue. Associated features are secondary burning and cut marks, especially near the joints, for dismemberment of the body (*e.g.* Hurlbut 2000). These resemble the butchering marks and patterns of animals (Lyman 1987). One can expect the discarded bones to end up among faunal refuse. On the bones at our disposal we do (occasionally) observe cut marks and secondary calcinations, while they have been discarded in dumps of faunal bone. The data are too few however to conclude that cannibalism played a role or lay at the root of these dispersed human remains.

5 Physical anthropology: demography and health

5.1 Sex and age profiles

The sex and age profiles of the sites presented here are statistically divided in intervals of 5 years (Acsádi & Nemeskéri 1970, 62).[4] Normal versus abnormal profiles will be discussed especially for the proportion of immature individuals. The sites and corresponding demographic data are divided in three groups, based on their age and geographic setting, each comprising two sites: 1) the Late Mesolithic sites, dating from *c.* 5500-4500 BC, namely Hardinxveld-Polderweg and De Bruin in the Dutch river area. 2) Swifterbant and Urk, dating from *c.* 4200-4000 BC and located in the middle of the Netherlands (the IJsselmeer Basin), and 3) Schipluiden and Ypenburg, both occupied at *c.* 3500 BC in the western coastal area. The graphs (Figs. 2-4) display the total number of individuals per age interval, as well as the number of adult male and female individuals.

The mortality curve of Hardinxveld-Giessendam is based on 19 people, 3 females, 8 males, 5 adults of unidentified sex and 3 children and subadults up to 20 years. The last group comprises *c.*15 % of the total population (fig. 6). The mean age at death for the adults was *c.* 43.5 years (women 43.3 and men 43.6 years). The presence of shed milk teeth shows, that the sites were used by family groups, including women and children. In view of these data one can conclude that these river dunes were inhabited by families and therefore served as a base camp.

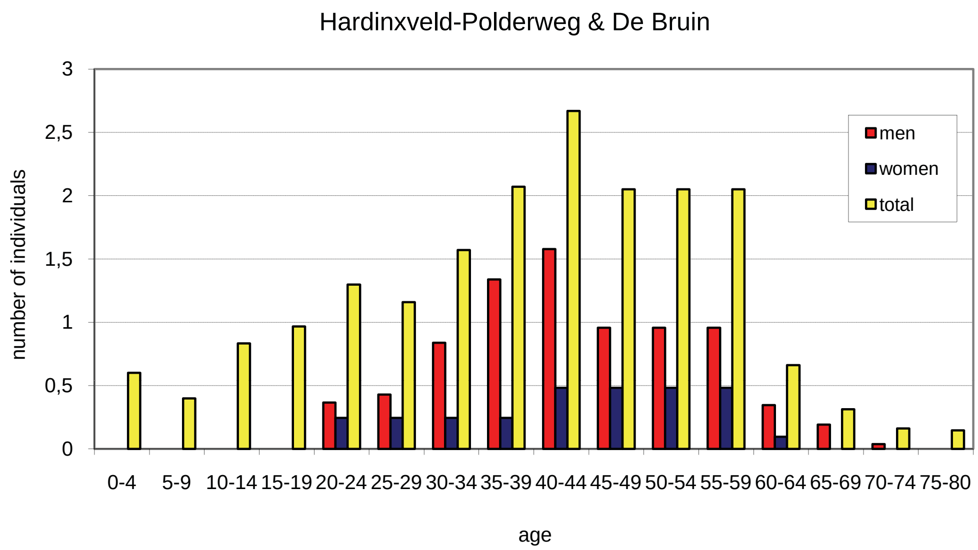

Fig. 6 Combined mortality profile of Hardinxveld-Giessendam.

At Swifterbant and Urk data on sex and age of a total of 69 individuals were available for the mortality profile. This group of adults consists of 10 men, 14 women and 30 individuals of unknown sex. Children and subadults (N=15) make up *c.* 22 % of the population (fig. 7). The mean age at death for the adults was *c.* 38 years (women 39.6 and men 36.3 years). The presence of women and children is consistent with the occupation of these sites by family groups. The total number of individuals at Schipluiden and Ypenburg amounts to 56, with 16 men, 11 women and 6 individuals of unknown sex. The mean age at death here is 38 years (women 33.5 and men *c.* 41 years). The percentage of children and subadults is, at *c.* 42.3 % much higher here (fig. 8). It seems that all members of the local group, the children below 5 years of age included, were buried in the Ypenburg cemetery during a certain stage of the occupation of the dune, irrespective of sex and age. Family groups must have occupied both sites, in view of the presence of children, but the number of women in Schipluiden is too low for a natural population. Evidently the small cemetery site on this dune does not reflect all the mortuary practices as the many isolated bones also indicate an above-ground ritual with disposing the dead, which left hardly any archaeologically detectable remains.

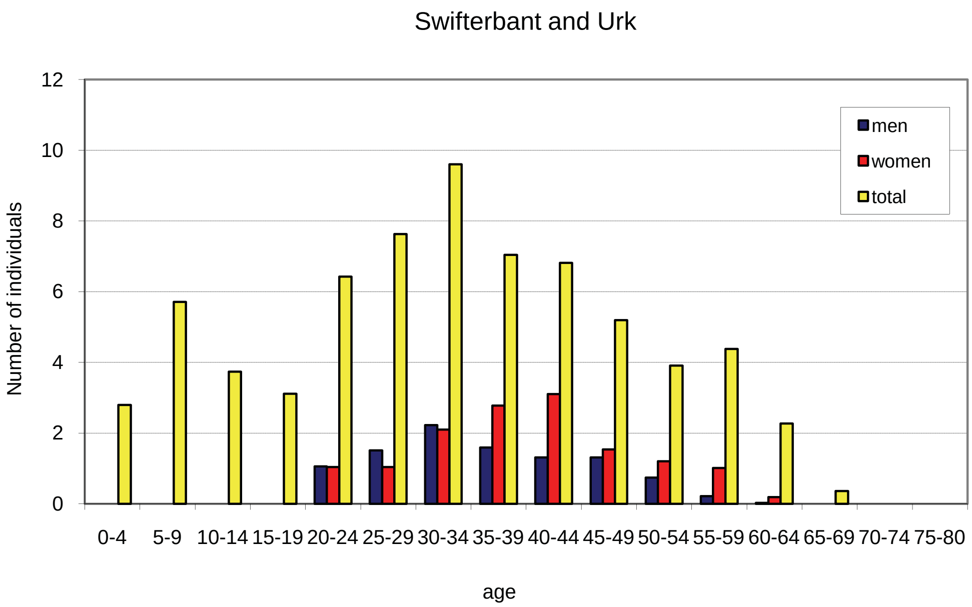

Fig. 7 Combined mortality profile of Swifterbant and Urk.

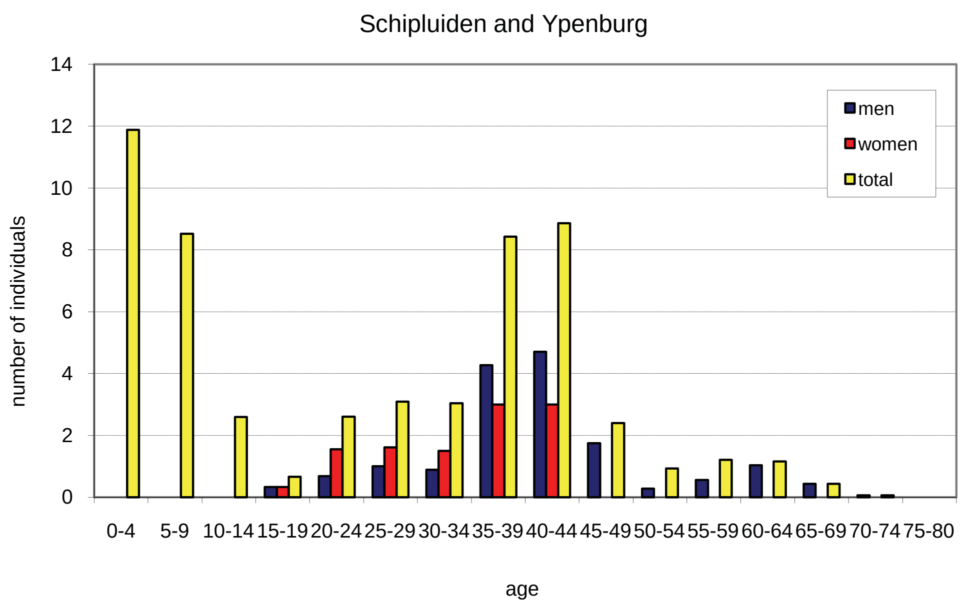

Fig. 8 Combined mortality profile of Schipluiden and Ypenburg.

The mortality profiles of the various populations are shown in figure 9. The percentages of young children and subadults are much higher for the combined series of Schipluiden and Ypenburg. The profiles of Hardinxveld-Giessendam, Swifterbant and Urk show an unnatural composition in this respect. Several factors could be responsible for this, such as preservation conditions, which can be unfavourable for young children, and an archaeologically elusive treatment of the dead. This restricts a comparison at the level of demographic analyses. The limited demographic data from these sites may, however, serve as a means of typifying the kind of settlement, to establish whether these were occupied by (complete) families or not. The data from Schipluiden and particularly Ypenburg give a fuller picture of the population structure, especially by the formal burials of young children. In terms of the adult-subadult ratio the data from these two sites show the most normal mortality curve with more than 40 % of individuals classified as subadult.

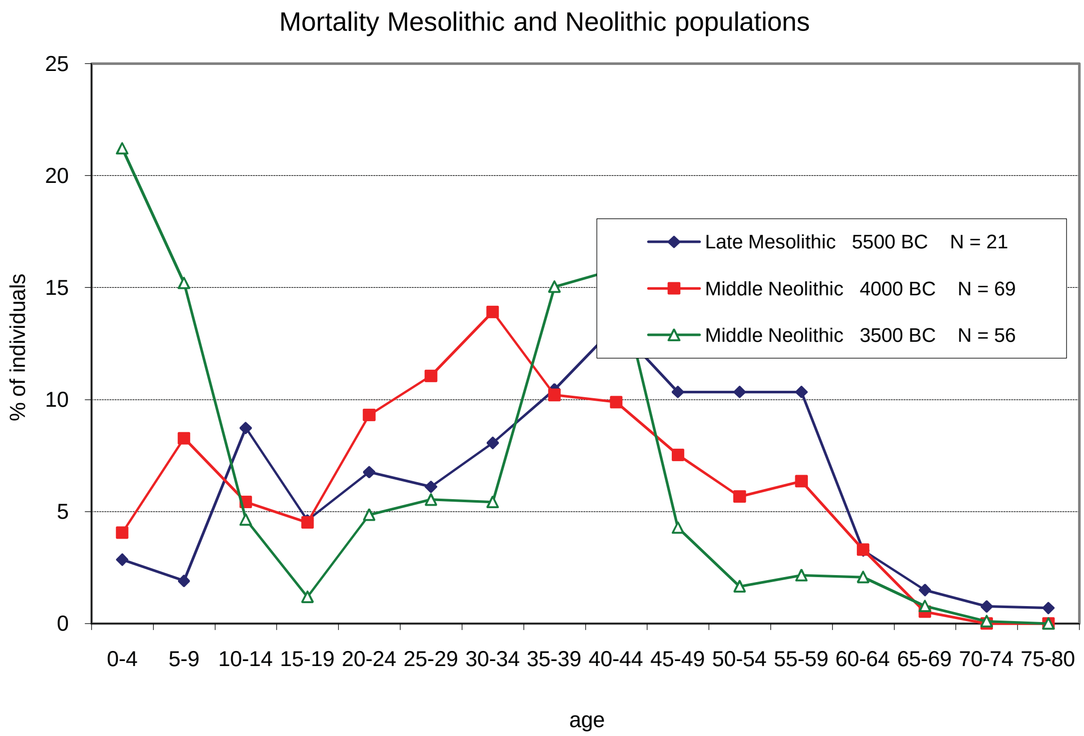

Fig. 9 Mortality profiles of late Mesolithic and Neolithic population in the Lower Rhine Basin.

5.2 Health

Skeletal remains can reveal some aspects of a person's health, but only some, as especially chronic diseases can lead to bone alterations, in contrast to short-term ones. The cause of death is rarely detectable from the skeleton. Pathological bone changes can be associated with a wide variety of phenomena such as bad health, hard physical labour and infectious diseases. Preservation will also affect the possibilities for observation; for instance, if spongy skeletal parts like the vertebral column and the joints of the appendicular skeleton are badly preserved no information on physical stress can be recorded.

At Polderweg pathological bone changes were not present. The preservation of the skeletons at Urk made any observations impossible. Swifterbant offers slightly better circumstances, some pathologies of a diverse nature were observed there, three of which involved peripheral arthritis. The population from Ypenburg appears to be best suited for the study of health. Enamel hypoplasia, a condition associated with spells of bad health during childhood (Hillson & Bond 1997), was observed in six cases there. Degeneration of the spine and peripheral joints (vertebral osteoarthritis and peripheral osteoarthritis) is the main feature present in the populations of Schipluiden (4 individuals) and Ypenburg (14 individuals). At both Schipluiden and De Bruin one incidence of trauma of a violent nature was recorded. This is probably the tip of the iceberg as lesions to the soft tissues like the organs cannot be studied. Dental pathology, especially caries, which is generally associated with diets rich in carbohydrates (Hillson 1979), was not observed in any of our populations. This may, however, be obscured in cases of heavy attrition of the teeth.[5]

The pathological features are on the whole inconclusive for the general health status, but the observations of those individuals that endured hard physical labour give at least an impression of the heavy daily workload corresponding to an agricultural way of life.

5.3 Stature

Information on stature is not available for all the groups discussed here. The data are shown in table 3. The preservation at Urk and Swifterbant made measurements for the calculation of statures impossible. For the women and men from Ypenburg stature seems to have been relatively small in comparison to the Late Mesolithic female skeleton of Polderweg and the values for the men at Schipluiden (table 3). The sparse data should, however, not be considered as representative, but more as indicative.

		Polderweg	De Bruin	Ypenburg	Schipluiden
♀	N =	1	-	9	-
	range	158 cm	-	149.6-161.1 cm	-
	mean		-	153.4 cm	-
♂	N =	-	2	8	5
	range	-	1.68-170 cm	153.5-170.5 cm	168-173.1 cm
	mean	-	169 cm	163.2 cm	1.73 cm

Stature is uncorrected for age as the health standard is of importance here and therefore the maximum stature is taken into account.

Table 3 Calculations of stature (in cm) for the populations in the Lower Rhine Basin, 5500-3500 cal BC. [6]

6 Stable isotope research: migration and diet

6.1 Migration

Stable isotopes of strontium ($^{87}Sr/^{86}Sr$), oxygen ($^{18}O/^{16}O$), sulphur ($^{34}S/^{32}S$) and lead ($^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$) of tooth enamel served to establish the area of childhood residence and therefore the provenance of individuals from Schipluiden and Swifterbant. Stable isotopes of these elements are bound to the local underground geology, influenced by altitude, precipitation and distance from the sea, and as such specific for a geographical area (Budd *et al*. 2004). The research was carried out in cooperation with the University of Durham and published elsewhere (Smits *et al.* 2008). Samples were taken from human enamel and associated soils horizons, animals and /or grave pits to establish the local isotopic make-up and to rule out possible diagenetic influences (postdepositional absorbtion). The Swifterbant population appeared to be more homogeneous and of local origin, than the population at Schipluiden, which was more heterogeneous. Two non-locally grown individuals could be pointed out for Schipluiden and one for Swifterbant in a total sample population of 20 individuals on the basis of the combined strontium, lead and oxygen evidence (see figure 6 for the combined Sr and O values). The result of the sulphur isotope study discriminates roughly between the two groups but interpretation in view of distance from the sea is hindered by possibly diagenetic influences and failing information on the local S values. The two Schipluiden non-locals have no deviating Sr values, but show oxygen signals pointing to origins in eastern (continental) and south-western (Atlantic) directions. One of these individuals showed high Pb values and a more terrestrial diet as well, supporting the interpretation as non-local. The Swifterbant 'immigrant' has been primarily separated on the basis of the non-local Sr values, supported by high Pb values and a distinct terrestrial $^{13}C/^{15}N$ isotopic signature. One of the presumed 'local' people at Schipluiden had, however, similar $^{13}C/^{15}N$ values. In all of the five Schipluiden burials only 'locals' were interred, while both 'immigrants' were identified among the three investigated isolated remains. This may be seen as an indication that mortuary practices for non-local individuals were different from those of local people at Schipluiden. We have to be careful with such a conclusion in view of the low numbers of analysed samples and the non-straightforward interpretation of the complex isotope data patterns. Future research should be especially directed to this presumed relationship of origin and mortuary practice.

As the local interred individuals were men and children one wonders whether this group was patrilocal and if women migrated from other regions, but as the skeletal remains of women are almost undetectable in the isolated remains this hypothesis cannot be researched here.

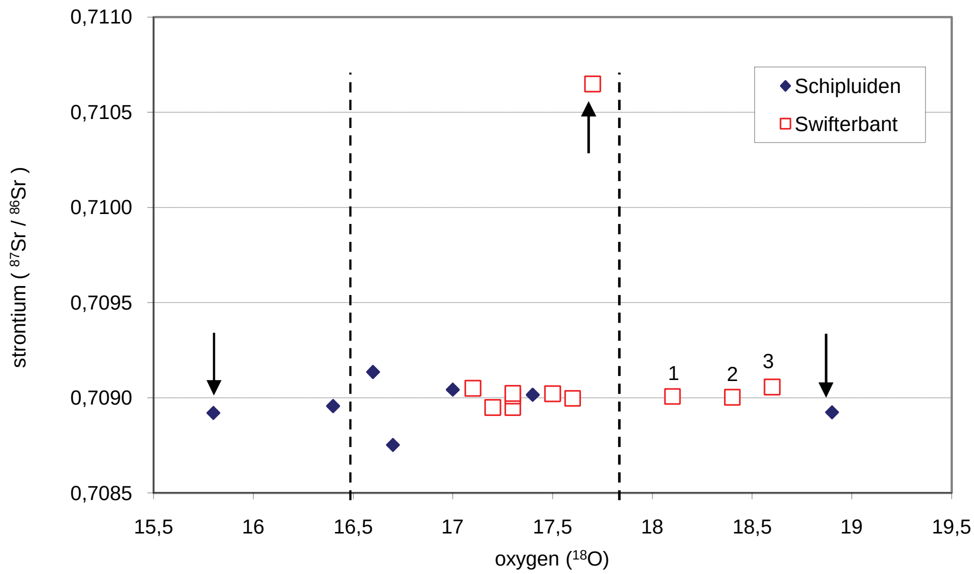

Fig. 10 Combined Sr and O values for Schipluiden and Swifterbant (data derived from Smits et al. 2008). The dashed lines indicates the range of local oxygen values, the arrows indicate immigrants. Nos 1 and 2 are children, no. 3 is an individual from a different site and possibly a different date.

6.2 Diet

The isotopic content of materials is expressed in the so-called delta (δ) values, which is defined as the deviation of the rare to abundant isotope ratio from that of a reference material (Mook 2006):

$$^{13}\delta = \frac{[\frac{^{13}C}{^{12}C}]_{sample}}{[\frac{^{13}C}{^{12}C}]_{reference}} - 1(\times 10^3 ‰) \quad and \quad ^{15}\delta = \frac{[\frac{^{15}N}{^{14}N}]_{sample}}{[\frac{^{15}N}{^{14}N}]_{reference}} - 1(\times 10^3 ‰)$$

For carbon, the reference material is the calcium carbonate in the shell of fossil belemnite from the PeeDee Formation (so-called PDB) in the USA. For Nitrogen, the reference is air (atmospheric N2). The stable isotope concentrations are measured by IRMS (Isotope Ratio Mass Spectrometry) at the Centre for Isotope Research in Groningen. The analytical error is 0.1 and 0.2 ‰ for δ ^{13}C and δ ^{15}N, respectively. The absolute rare isotope contents of these standards can be found in Mook (2006).

The stable isotope ratios δ ^{13}C and δ ^{15}N discussed here are measured for bone collagen extracted from the samples (Longin 1971; Mook & Streurman 1983).

The stable isotope ratio of carbon has been measured routinely by the ^{14}C laboratories since the 1960's. The reason is that this is used for the correction of ^{14}C dates for isotopic fractionation, by using $\delta\, ^{14}C = 2\delta\, ^{13}C$. Thus, for both human and animal bone collagen, a wealth of data exist for this stable isotope ratio $\delta\, ^{13}C$ for all materials dated, including bone collagen (Van Klinken *et al*. 2004). During the last two decades or so, this information has been supplemented with measurements of the stable isotope of nitrogen, $\delta\, ^{15}N$, in bone collagen.

In this section, new $\delta\, ^{13}C$ and $\delta\, ^{15}N$ stable isotope data are discussed for Hardinxveld and Schipluiden. It is in part an update from earlier work, which included Swifterbant (Smits *et al*. 2008). Here we discuss the data in terms of the paleodiet. The data will also be used in a study to determine the ^{14}C reservoir effects for human skeletal material. We mention here only the Hardinxveld burial of an adult woman. Based on the $\delta\, ^{15}N$ value, the assumption of a fluviatile diet and using the procedure developed by Cook *et al*. (2001) for the Iron Gates Mesolithic sites, the size of the ^{14}C reservoir effect for this individual is preliminarily established as being no more than 350 years.

The $\delta\, ^{13}C$ for humans and animals living on land are part of the terrestrial food chain. Typical $\delta\, ^{13}C$ values for bone (based on a C3 diet) are around -21 ‰ (Lanting & van der Plicht, 1995/'96, 1998). The isotope content for organisms living in water (rivers or the sea) is different. The $\delta\, ^{13}C$ starting point of the trophic chain in water is more positive. Where 'terrestrial' bone collagen shows on average $\delta\, ^{13}C \approx -21$ ‰, 'marine' foods give a much higher $\delta\, ^{13}C$ content: $\delta\, ^{13}C \approx -13$ ‰. For freshwater, the situation is more variable. There the $\delta\, ^{13}C$ may be more positive than in terrestrial systems, but can also be the same or even more negative.

The isotope $\delta\, ^{15}N$ is in particular important for the observation of marine or fresh water dietary components. Terrestrial human bone collagen shows ^{15}N values of typically 5-10 ‰, depending on the food source. The $\delta\, ^{15}N$ values are much higher for a 100 % diet of marine or fresh water food: about 16-18 ‰ (Schoeninger *et al.* 1983). As food passes from the trophic level of the producer to the consumer, there is enrichment in both $\delta\, ^{13}C$ and $\delta\, ^{15}N$. This applies to both the terrestrial and the marine environment. Producers/consumers can be for example plants/herbivores, or herbivores/carnivores. In bone collagen, there is a ≈ 1 ‰ increase in $\delta\, ^{13}C$ and a ≈ 3 ‰ increase in $\delta\, ^{15}N$, per step in the trophic level. This observation spawned the intriguing title of a key review paper on paleodiets: "you are what you eat, plus a few permil" (Kohn 1999).

A series of $\delta\, ^{13}C$ and $\delta\, ^{15}N$ measurements were obtained for Schipluiden and Hardinxveld. Data were obtained for fossil bones from both sites, and from food residues in cooking vessels. The data are shown in tables 4 and 5, respectively. The list includes quality parameters like carbon content (% C), nitrogen content (% N) and (for the bones) the C/N ratio. The latter is a key quality parameter for bone collagen, used in particular for quality assessment of ^{14}C dates. A plot of $\delta\, ^{13}C$ versus $\delta\, ^{15}N$ for the human bone samples from both sites is shown in figure 11. Also included in the figure, are earlier measurements for Swifterbant measured at Durham, UK (Smits *et al*. 2008). These Swifterbant data are obtained on dentine; in this case, no data are available for bone collagen.

sampler*	sample name	species	scientific name	$\delta^{13}C$	$\delta^{15}N$	C%	N%	C/N
Hardinxveld-De Bruin								
43658	De Bruin 11014	human	*Homo sapiens*	-21,61	15,78	42,4	14,45	2,9343
42082	De Bruin 11254	human	*Homo sapiens*	-23,04	13,29	38,5	16,2	2,3765
43659	De Bruin 15165	human	*Homo sapiens*	-21,52	15,68	40	11,15	3,5874
22277	De Bruin 20685	human	*Homo sapiens*	-21,4	17,2	25,1	7,2	3,4861
22278	De Bruin 20686	human	*Homo sapiens*	-21	16,5	28,2	15,8	1,7848
42085	De Bruin 7678	deer	*Cervus elaphus*	-22,53	3,37	38,5	16,45	2,3404
42089	De Bruin 8111	deer	*Cervus elaphus*	-23,11	5,11	38,9	14,2	2,7394
42097	De Bruin 9348	deer	*Cervus elaphus*	-22	4,05	38,1	16	2,3812
42100	De Bruin 9758	elk	*Alces alces*	-22,6	3,57	41,2	18,05	2,2825
42102	De Bruin 13436	wild boar	*Sus scrofa / domesticus*	-21,16	5,99	37,8	14,65	2,5802
42103	De Bruin 13580	wild boar	*Sus scrofa / domesticus*	-20,61	6,2967	37,7	15,6	2,4167
42098	De Bruin 7325	pig	*Sus scrofa / domesticus*	-20,96	4,78	45,9	14,65	3,1331
42084	De Bruin 2166	beaver	*Castor fiber*	-22,44	5,265	37,7	15,2	2,4803
42095	De Bruin 19313	dog	*Canis familiaris*	-23,26	12,723	38,941	16	2,4338
42104	De Bruin 7906	cormorant	*Phalacrocorax*	-14,14	15,21	42,6	13,15	3,2395
42105	De Bruin 6015	swan	*Cygnus*	-15,32	2,795	43,3	13,4	3,2313
Hardinxveld-Polderweg								
41945	Polderweg 11159	human	*Homo sapiens*	-22,03	14,6	36,6	16,3	2,2454
41939	Polderweg 11941	human	*Homo sapiens*	-20,81	15,27	36,3	14,6	2,4863
41948	Polderweg 13883	human	*Homo sapiens*	-20,26	16,695	37,2	14,5	2,5655
41943	Polderweg 14679	human	*Homo sapiens*	-22,39	14,817	35,2	13,95	2,5233
41941	Polderweg 15661	human	*Homo sapiens*	-21,8	14,953	37,9	13,85	2,7365
41944	Polderweg 22423	human	*Homo sapiens*	-21,89	14,667	35,4	14,75	2,4
41949	Polderweg 22639	human	*Homo sapiens*	-22,17	14,945	41,5	15,4	2,6948
41946	Polderweg 23097	human	*Homo sapiens*	-19,96	9,8767	39,9	14,05	2,8399
41947	Polderweg 24337	human	*Homo sapiens*	-21,68	14	38,9	17,15	2,2682
41937	Polderweg 6654	human	*Homo sapiens*	-22,3	14,63	31,3	14,8	2,1149
41952	Polderweg 7000	human	*Homo sapiens*	-22,3	14,033	38,7	13,6	2,8456
41942	Polderweg 7881	human	*Homo sapiens*	-22,07	15,4	34,8	14,5	2,4
41936	Polderweg 8644	human	*Homo sapiens*	-21,86	14,43	37,5	14,4	2,6042
22019	Polderweg 24038	human	*Homo sapiens*	-23,95	16,5	45,2	15,76	2,868
43657	Polderweg 26100.4	human	*Homo sapiens*	-22,47	13,885	33,2	10,9	3,0459
41951	Polderweg 10297	human	*Homo sapiens*	-22,81	13,305	35	14,35	2,439
42127	Polderweg 10441	deer	*Cervus elaphus*	-21,31	4,11	44,3	15,55	2,8489
42130	Polderweg 20259	deer	*Cervus elaphus*	-22	5,835	42,5	15,45	2,7508
42116	Polderweg 23995	deer	*Cervus elaphus*	-23,41	1,01	42	14,2	2,9577
42126	Polderweg 26699	deer	*Cervus elaphus*	-21,92	3,985	40	14,1	2,8369
42115	Polderweg 27887.11	deer	*Cervus elaphus*	-21,99	5,02	41,7	13,8	3,0217
42133	Polderweg 22083	roe	*Capreolus capreolus*	-19,99	11,885	43,9	15,75	2,7873
42123	Polderweg 19560	wild boar	*Sus scrofa / domesticus*	-20,46	7,52	40	13,65	2,9304
42114	Polderweg 24507	wild boar	*Sus scrofa*	-21,84	4,89	43,8	12,25	3,5755
42131	Polderweg 24073	pig	*Sus scrofa / domesticus*	-22,29	5,83	42,6	14,8	2,8784
42128	Polderweg 25799	pig	*Sus scrofa / domesticus*	-22,52	5,12	40,6	14,05	2,8897
42132	Polderweg 24054	beaver	*Castor fiber*	-20,94	5,05	41,7	15,05	2,7708
42118	Polderweg 25065	otter	*Lutra lutra*	-25,46	9,66	41,2	13	3,1692
42120	Polderweg 28038	otter	*Lutra lutra*	-21,03	9,505	38,2	11,8	3,2373
25219	Polderweg 3	seal	*Phoca vitulina*	-13,69	18,7	43,3	16,1	2,6894
42124	Polderweg 11287	dog	*Canis familiaris*	-21,34	11,635	43,1	15,3	2,817
22018	Polderweg 8350	dog	*Canis familiaris*	-20,5	15	39,1	13,7	2,854
42125	Polderweg 25797	duck?	*Anas platyrhynchos*	-24,88	11,67	41,3	14,3	2,8881
Schipluiden								
34921	Schipluiden 1/1	human	*Homo sapiens*	-18,67	15,7	35	11,9	2,9412
34922	Schipluiden 1/2	human	*Homo sapiens*	-19,02	15,955	36,5	12,8	2,8516
34923	Schipluiden 2	human	*Homo sapiens*	-18,81	15,66	30,8	12,1	2,5455
34924	Schipluiden 3	human	*Homo sapiens*	-21,52	12,79	36,4	13,8	2,64
36346	Schipluiden 3/4	human	*Homo sapiens*	-21,56	13,445	39,6	14,1	2,8085
34925	Schipluiden 4	human	*Homo sapiens*	-20,5	10,07	26	9,3	2,8
36347	Schipluiden 4/5	human	*Homo sapiens*	-19,34	15,71	30,8	12,45	2,4739
34927	Schipluiden 6	human	*Homo sapiens*	-21,05	16,725	34,2	13,75	2,4873
41955	Schipluiden 4018-16	otter	*Lutra lutra*	-18,12	13,89	31,6	13,7	2,3066
43656	Schipluiden 13112	sturgeon	*Acipenser sturio*	-21,6	12,28	8,4	2,5	3,36

* sample number Centre for Isotopic Research, Groningen

Table 4 Stable isotope ratios for bones from Schipluiden and Hardinxveld.

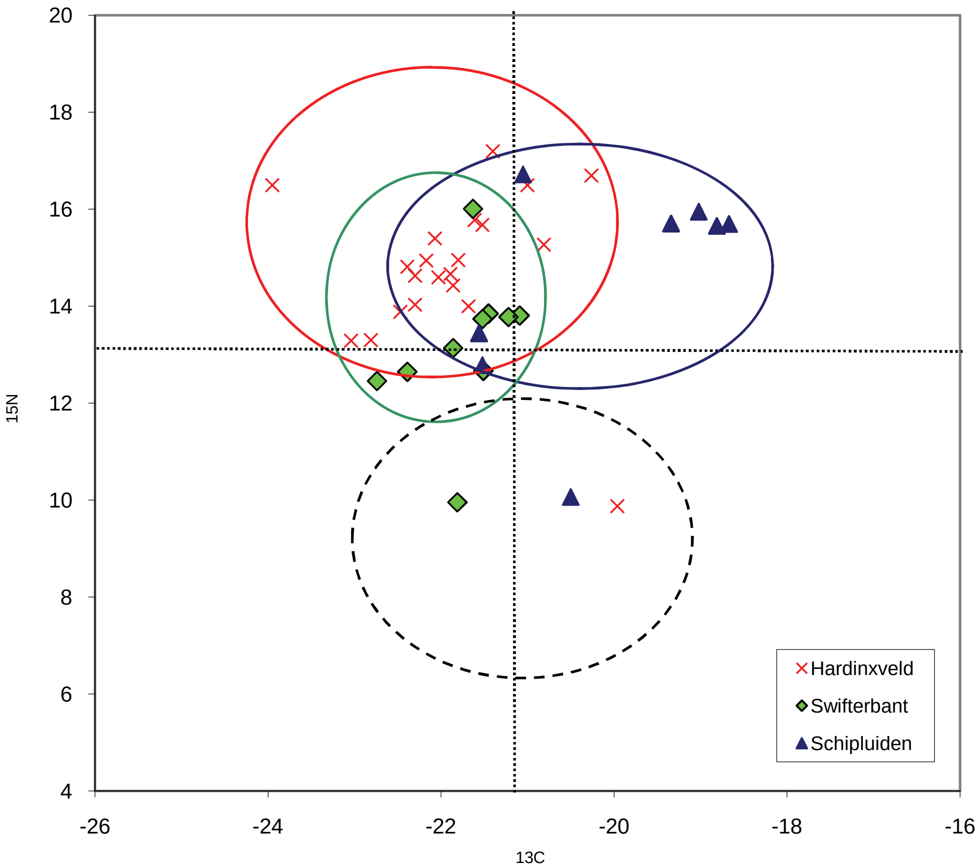

Fig. 11 Stable isotope ratios δ ^{13}C and δ ^{15}N for human bones (Hardinxveld, Schipluiden; this paper) and published values for dentine from Swifterbant (Smits et al. 2008).

The region indicated in figure 11 by by a dashed circle comprises a total of about 200 δ ^{13}C and δ ^{15}N values for human bones from the Groningen database. These are human bones submitted for ^{14}C dating, for which also δ ^{13}C and δ ^{15} N has been measured, representing all regions in the Netherlands and ^{14}C ages (Kuitems 2007).

The δ ^{13}C and δ ^{15}N values for Schipluiden, Hardinxveld and Swifterbant are clearly higher in ^{15}N than the general values from the database. This is a strong indication of an aquatic food source for these populations. The δ ^{13}C and δ ^{15}N values for the three populations occupy different regions in the δ ^{13}C/δ^{15}N plot, as is tentatively indicated by the ellipses in figure 11.

The samples from Schipluiden and Hardinxveld show more elevated values for the stable isotope ratio δ ^{15}N. This indicates that the aquatic dietary component is larger than for Swifterbant, the latter being (slightly) more terrestrial. Based on the stable isotope research for the human bones, Smits *et al*. (2008) concluded earlier that the Swifterbant population represents a mixed diet, and Schipluiden a more aquatic diet. The data from Hardinxveld form an extension of our dataset, confirming this observation. The Hardinxveld bones are slightly more depleted in δ ^{13}C, and show elevated values for δ ^{15}N, which is consistent with an aquatic food source. On the whole the Schipluiden group shows less depleted values of δ ^{13}C, compared with the two other sites, indicating a distinct marine component in the diet.

Apart from these general conclusions, there is clearly one 'outlier' for each site, apparently individuals with a terrestrial diet. At Swifterbant; an isolated molar with a distinctly lower δ ^{15}N value, belonged to an immigrant, based on other isotopic investigations (Smits *et al* 2008 and above). The Hardinxveld sample consists of an unarticulated bone, from which no additional isotopic information is available, nor an accurate age or sex diagnosis. The Schipluiden individual, man of *c.*25-40 years at death, had *no* divergent values for the other isotopes and should be considered as locally (*i.e.* in the region) grown up.

In order to investigate food sources for the prehistoric population, a series of stable isotope ratios ^{13}C and ^{15}N was measured for a relatively large spectrum of animals: otter, beaver, deer, dog, pig, wild boar, elk, seal, various water birds and sturgeon (fig. 12). These samples are a representative fauna in terms of associated bones found at both sites.

The ^{13}C and ^{15}N values for both this fauna and for the humans from the three locations are shown in figure 12.

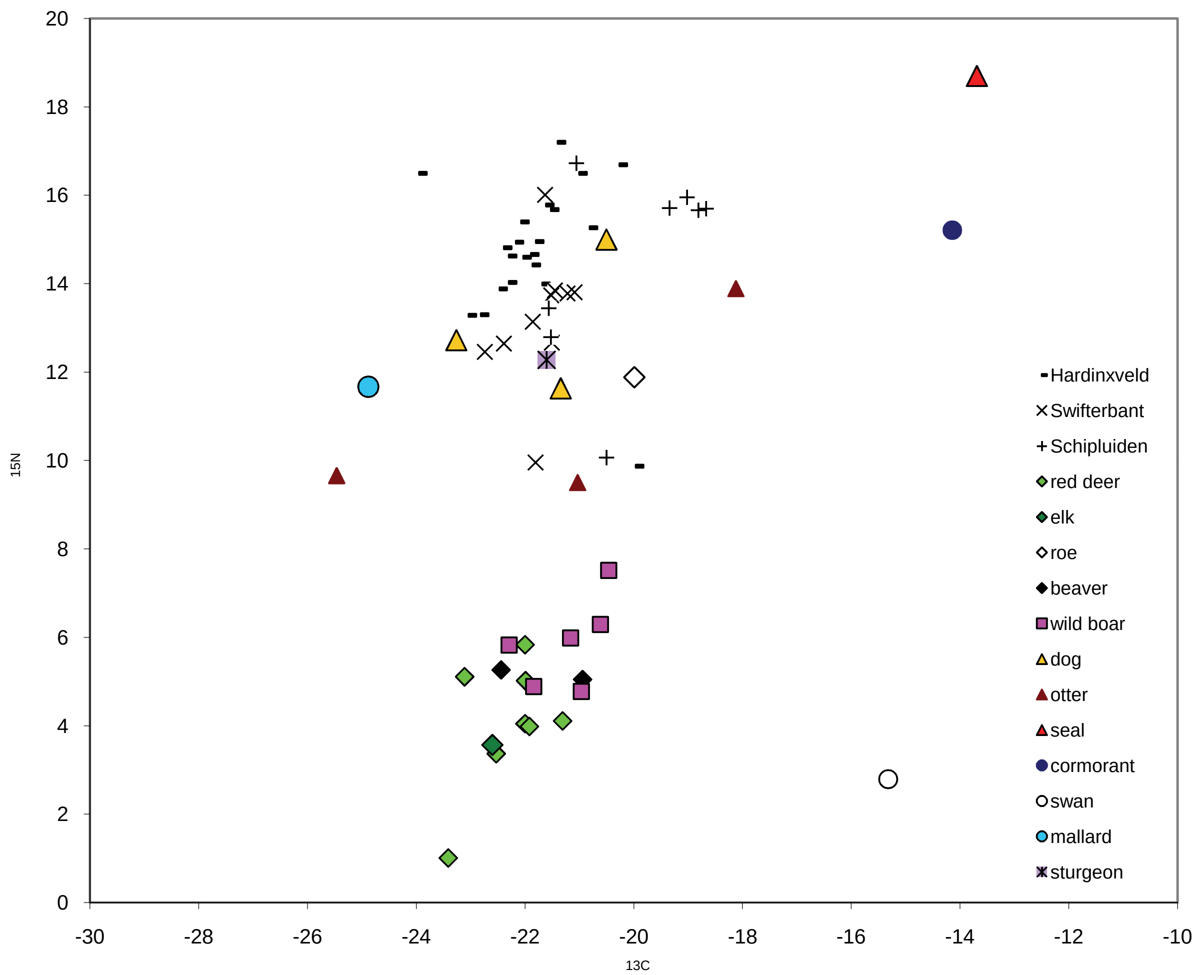

Fig. 12 Stable isotope ratios δ ^{13}C and δ ^{15}N for bone collagen from various animals; also the human data (fig. 11) are included for comparison.

The three data points for otter cover a broad range in isotope ratio values for which no explanation is at hand. It is known that otters can live from either marine or freshwater food sources. Otters also show a broad range of reservoir effects in their ^{14}C dates. The two data points for beaver are consistent in the herbivore regime. In the Groningen database, there are 5 stable isotope measurements for beaver from the province of Drenthe, the Netherlands. These show similar δ ^{13}C values, but the δ ^{15}N values range between 1 and 6 ‰. The results for the deer all plot in the herbivore region, with one exception; one roe shows an unexpectedly high δ ^{15}N value. High δ ^{15}N values are known for bones of herbivores living in arid areas and in coastal regions. This is a subject of further investigation. The values for the series of pigs and wild boars also show up in the herbivore region, generally ranging between -19.5 and -22 ‰ for δ ^{13}C, and between 4 and 9 ‰ for ^{15}N (Kuitems 2007). Two domesticated dog bones plot higher than the pigs and wild boars but lower than the humans, which is expected concerning their position in the trophic level. Values generally range between -21.0 and -23.0 ‰ for δ ^{13}C, and between 9 and 15 ‰ for δ ^{15}N (Kuitems 2007). There is one measurement for elk in the present dataset. The δ ^{15}N values for this species are known to be low. The isotopic value falls in the range of a series of 17 animals from the Netherlands, with δ ^{13}C values ranging between -21 and -23 ‰, and δ ^{15}N values between 1.5 and 4 ‰ (Van Klinken 2005). The δ ^{13}C and δ ^{15}N values for only one fish bone (sturgeon) could be measured. A larger series of sturgeon bones did not produce good quality collagen or no collagen at all. The δ ^{15}N value plots below the human values. Three bird bones yield δ ^{13}C and δ ^{15}N values: duck, swan and cormorant. They show extreme values on the stable isotopes chart. The duck has (δ ^{13}C, δ ^{15}N) = (-24.9 ‰, 2.8 ‰), the swan (δ ^{13}C, δ ^{15}N) = (-15.3 ‰, 11.7 ‰), and the cormorant (δ ^{13}C, δ ^{15}N) = (-14.1 ‰, 15.2 ‰). Modern (non-prehistoric) ducks are the subject of migration studies by biologists. The δ ^{13}C and δ ^{15}N values of their bones are not understood. For example, in Northern Canada the values of δ ^{13}C range from -22 to -16 ‰, and the δ ^{15}N values from 9 to 15 ‰, not depending on freshwater versus marine gradients as was expected, but on regional effects and biological factors such as the sex of the animal (Braune *et al.* 2005). The cormorant δ ^{15}N value is very similar to those obtained from a stork from the province of Drenthe, the Netherlands, the Groningen database: (δ ^{13}C, δ ^{15}N) = (-18.59, 14.2) ‰. One data point for seal is obtained, with δ ^{13}C and δ ^{15}N values as expected.

In general, the stable isotopes shown in figure 12 are consistent with what is to be expected, concerning the trophic chain. The human bones are 3-5 ‰ in ^{15}N higher than the food sources such as sturgeon.

Radiocarbon dates of food residues on pottery from Northern European inland areas are clearly influenced by freshwater reservoir effects, caused by fish and molluscs cooked in the pots. The food residues are shown to have possible ^{14}C age excesses up to 300 years (Fischer & Heinemeier 2003).

In this study, we analysed food residues from Schipluiden for the stable isotopes δ ^{13}C and δ ^{15}N. We refer to food residues as charred, dark residue with a thickness up to a few mm, which adhere to the inner surface of cooking pottery. A total of 11 samples were analysed, following the procedure of Morton & Schwartz (2004). The values are presented in table 5 and depicted in figure 13. Values from Tybrind Vig, Denmark (Craig *et al*. 2007) are shown as well. The δ ^{15}N values display similar values; the δ ^{13}C values, however, are clearly less negative. This is possibly a coastal/inland effect. From Amose (Denmark), Fischer & Heinemeier (2003) analysed the food remains for δ ^{13}C and ^{14}C (dating), but included no δ ^{15}N isotopes. They observe a change at a δ ^{13}C value of -26 ‰ for Stone Age sites from Northern Europe. This is the average value of terrestrial food, and of some mixtures of marine and freshwater components. More negative δ ^{13}C values correspond to marine samples, and less negative to freshwater samples (Fisher and Heinemeier, 2003). The δ ^{13}C values from the coastal sites are generally more positive than those from the inland sites, which would imply that marine species formed a substantial part of the food cooked in the pots at coastal sites.

Following this observation from Denmark, we note that the majority of the Schipluiden food residues (8 out of 11) show δ ^{13}C 15N values are elevated, with one exception, which supports this conclusion. The exception shows the lightest δ ^{13}C value: δ ^{13}C = -22 ‰, and also has the lowest δ ^{15}N value: δ ^{15}N = 5 ‰. Most likely, this vessel has been used for the cooking of (mainly) terrestrial food.

sample *	sample name	δ^{13}C	δ^{15}N	C%	N%
42448	4048	-26,13	9,93	45,9	1,4
42449	1059	-26,8	9,975	41,9	2,4
42450	7292	-22,03	4,985	67,9	5,2
42451	340, 341, 342	-24,18	11,26	44,9	5
42452	6435	-26,94	9,235	22,4	1,2
42453	5431	-28,9	9,505	8,9	5,6
42454	10164	-27,1	11,425	39,3	3,4
42455	9279	-23,3	10,43	66,7	6,2
42456	3407	-27,06	10,265	49,1	6
42457	4737	-26,07	10,865	46,8	2,8
42458	9373	-25,99	11,215	39,4	6

* sample number Centre for Isotopic Research, Groningen

Table 5 Stable isotope ratios for food residues from Schipluiden.

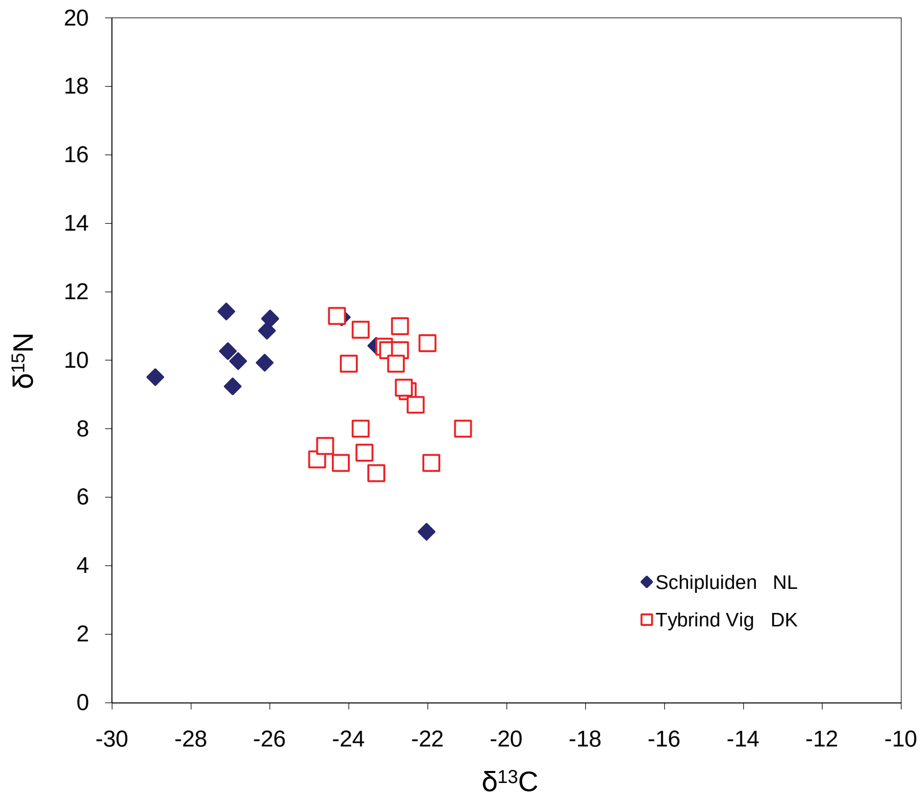

Fig. 13 Charred remains from cooking vessels from Schipluiden (this paper), compared with values from Denmark (Craig et al. 2007).

7 Discussion and conclusions

7.1 Mortuary variability

A rough division can be made in three groups as far as the depositions of the human skeletal remains are concerned: inhumation graves, cremation remains in settlement context and scattered human bones. The inhumation graves show diversity in the disposal of the dead. There were single, double and multiple inhumation graves and the remains were either complete or incomplete.

From the Mesolithic period burials are scarce and appear to have been either isolated or in small burial grounds for instance at Vedbæk and Skateholm in Scandinavia, at Téviec and Hoëdic in Brittany (Albrethsen & Brinch Petersen 1976; Larsson 1990; Péquart & Péquart 1929, 1934, 1954; Péquart *et al.* 1937). The most frequent burial posture is supine with stretched limbs. Burials in which the deceased was buried in a sitting position, like one burial at De Bruin, are also attested at several other European sites, Bäckaskog in Skåne and Lummulunda on the isle of Gotland, Sweden (Stenberger 1962, 36; Newell & Constandse Westermann 1979). We may deduce that the observed traditions seem to be in accordance with those in northwest Europe for the late Mesolithic period. At Swifterbant and Urk the same burial posture is attested.

A change from a stretched to a position on the side with flexed limbs evidently took place before or around *c.* 3500 BC. This phenomenon is known from several burials associated with the Michelsberg culture in the south (Ilett & Coudart 1983). Stable isotope analysis has shown that two individuals from Schipluiden probably originate from other areas including the southern regions. This indicates either migration and/or other contacts. Liaisons with these people may have been at the root of new traditions including the treatment of the dead.

Most sites have yielded scattered, unarticulated, human bones and bone fragments as well as formal burials. These remains can indicate a variety of processes and actions. They can be the result of taphonomic processes, related to an archaeologically invisible above-ground treatment of the dead for which again many options exist. One is a mortuary ritual like excarnation in the open, on a platform. After a certain period the bodies are decomposed or defleshed and (secondarily) buried or discarded. Secondly, there may have been fighting between members of the group or with outsiders, leading to discarding of the remains of slain enemies, to trophy hunting, or even cannibalism. Thirdly, an unnatural death or mysterious disease can also lead to a different manner of handling the body resulting in the observed spectrum. Furthermore postdepositional disturbances of formal burials can cause the dispersion of bones as well.

7.2 Demography

There are several restrictions in reconstructing the composition of prehistoric populations on the basis of the present evidence. First of all there is the question of representativeness of the human remains for the population at large. The demographic investigation is frustrated by the apparent different treatment of young children and infants, and especially by the archaeologically elusive above-ground treatment of the dead. Postdepositional processes like preservation circumstances have caused loss of bone material as well. The scattered bones, moreover, offer limited opportunities for sex and age diagnosis, so a large part of the groups of individuals concerned remains unspecified.

Demographic studies are often directed at the establishment of the growth rate of populations – were they stable, declining or growing – in spite of the fact that age distributions of skeletons are often biased. A rise in the percentage of subadults between 5 and 19 years from *c.* 20 to 30%, as based on skeletal evidence for 68 European Mesolithic and Neolithic populations, would indicate population growth for the early Neolithic period (Bocquet-Appel & Dubouloz 2004). Jackes *et al.* (2008) argue for a stable Mesolithic population and a growing Neolithic one based on the fertility parameters of the populations of among others Lepenski Vir and Vlasac in the Đerdap/Iron Gates gorge in south-east Europe. In view of the general background the data at our disposal from the populations in the Lower Rhine Basin are presented in table 6 in reference to other European Mesolithic and Neolithic series. This table is condensed after Bocquet-Appel (2002) and adapted using data from Jackes *et al.* (2008) and our populations from the Lower Rhine Basin.

Generally the Neolithic skeletal series display a higher proportion of juveniles between 5-19 years (based on the table published by Bocquet-Appel 2002). The values presented in table 6 show a mean ratio for the immature individuals of 0.189 (sd = 0.061) for the Mesolithic and 2.214 (sd = 0.078) for the Neolithic groups. The series of Hardinxveld-Giessendam and Swifterbant/Urk show a low proportion of immatures, with values well below 0.2. This could be indicative of a declining population, but these cases probably display biased distributions. These data are therefore interpreted as not representative of the underlying groups, but they are a welcome basis for the (qualitative) assessment of the group composition. The pooled data for Ypenburg and Schipluiden on the other hand show a proportion of juveniles of 0.267, which is well above average in comparison with other Neolithic groups. The mortality for the age interval 0-4 years is considerable as well at *c.*21%. We can conclude that these data are representative for the population at large and tentatively indicate population growth.

	age (years)					
site	0-4	5-19	20+	total	$_{15}P_5$ *	reference
Mesolithic populations						
Djerhap	53	22	112	187	0,1641	Jackes *et al.* 2001
Hardinxveld Polderweg and De Bruin (pooled data)	0,6	2,2	16,2	19	0,1195	Smits & Louwe Kooijmans 2001; Louwe Kooijmans & Smits 2001
Lepenski Vir	20,6	5	14,9	40,5	0,2513	Jackes *et al*. 2008
Skateholm	6	8	44	58	0,1538	Meiklejohn *et al.* 1997
Vedbæk	5	5	13	23	0,2777	Jackes *et al.* 2008
Vlasac	30,6	16,4	81,9	128,9	0,1668	Jackes *et al*. 2008
Neolithic populations						
Aiterhofen	5,4	21,43	115,17	142	0,1569	Nieszery 1995
Lepenski Vir	5,3	11,4	42,2	58,9	0,2127	Jackes *et al.* 2008
Nitra	12	13	47	72	0,2166	Pavúk 1972
Schipluiden and Ypenburg (pooled data)	11,88	11,78	32,33	56	0,2671	Smits & Louwe Kooijmans 2006; Baetsen 2008
Sondershausen	4,2	10,8	32	47	0,2523	Bach 1978
Swifterbant and Urk (pooled data)	2,8	12,56	53,64	69	0,1897	Constandse-Westermann & Meiklejohn 1979; Peters & Peeters 2001
Wandersleben	38	60	118	216	0,337	Bach 1986
Zengövárkony	3	5	56	64	0,0819	Zoffmann 1969-'70

* Proportion individuals of 5-19 years, after Bocqet-Appel & Paz de Miguel Ibánez 2002; *cf.* paragraph 2.

Table 6 Demographic parameters of Mesolithic and Neolithic populations (data partly derived from Bocquet-Appel 2002).

7.3 Health

The skeletal remains from the Ypenburg population are the most informative on the topic of health in comparison to the other groups in the Lower Rhine Basin. The pathological traits show a variety, of which degeneration of the joints and the spine is the most common. This can be related to a sedentary lifestyle and physical labour (Baetsen 2002).

For comparison the information on stature of various Mesolithic and Neolithic groups is presented in table 7 (after Formicola & Gianecchini 1999). The values of the Ypenburg population are comparable to those of Skateholm, Téviec and Hoëdic. The data from Hardinxveld-Giessendam and Schipluiden resemble those of Bandkeramik farmers. Although data are sparse we can deduce that the stature at Ypenburg was rather low compared to several other Mesolithic and Neolithic European groups (table 7). Conclusions on the health status of the populations of Hardinxveld, Swifterbant and Schipluiden cannot be made due to the restricted data. There are, however, several indications of the health of the Ypenburg population to be able to draw tentative conclusions. These are a rather high infant mortality, low stature, and skeletal markers of physical stress. Although fertility was indicative of a growing population this leads us to question whether living conditions were as favourable, as has been suggested by the zooarchaeologists (De Vries in Koot *et al.* 2008).

	males			females			
site	N =	mean	sd	N =	mean	sd	reference
Skateholm	23	163,5	6,7	23	151,4	4,5	Persson & Persson 1988
Téviec/Hoëdic	10	161,4	5,4	12	150,7	4,2	Vallois & Felice 1977
Vlasac	14	172,5	6,2	12	159,5	5,2	Nemeskeri & Szatmary, unpublished manuscript
Bandkeramik Saale	46	165,8	3,7	47	156,6	1,9	Bach 1978
Polderweg	-	-	-	1	158		Smits & Louwe Kooijmans 2001
De Bruin	2	169	2	-	-	-	Louwe Kooijmans & Smits 2001b
Schipluiden	5	169	2,3	-	-	-	Smits & Louwe Kooijmans 2006
Ypenburg	8	163,2	2,9	9	153,4	4,1	Baetsen 2008

Table 7 Stature of Mesolithic and Neolithic populations (data partly derived from Formicola & Giannecchini 1999).

7.4 Migration

As strontium values are bound to geological formations the results can be less distinctive as we would like because the underground formations of a region can be quite homogeneous. Multiple isotope analyses of additional elements like – especially – oxygen improves the possibility to discriminate between locals and non-locals. This is illustrated by one immigrant at Swifterbant, which shows deviant Sr but local O values and two individuals at Schipluiden with normal Sr but deviant O values. Lead isotope analyses are in accordance with these findings and therefore strengthen the interpretation.

The combination of the various isotope studies on provenance and diet offer the possibility to elucidate inter-individual variety in diet as well. This is shown by the fact that some of the immigrants displayed a diet lower in fish. When relating these observations to the burial ritual it appears that all the people in the graves at Schipluiden were of local origin, and that both immigrants are represented by isolated molars only, bearing witness to an above-ground treatment of the dead. Differences with respect to gender cannot be studied as females are underrepresented in Schipluiden. A future isotope study of the Ypenburg population would be desirable and a valuable addition to this topic.

7.5 Diet

The Mesolithic samples show a distinct aquatic component, but the diet seems to have been mixed and rather complex, perhaps to be associated with a variable habitation regime throughout the year, the river area in winter and (possibly) the higher areas at other times of the year. Mesolithic diets in Denmark also display a complex nature with a terrestrial and aquatic component (Richards *et al.* 2003b). In the Meuse valley the Mesolithic diet was mixed with a major terrestrial signature (Bocherens *et al.* 2007).

The population of Swifterbant had a diet with a larger proportion of protein from terrestrial sources, but also with an aquatic element. The ^{13}C values are comparable with the Mesolithic samples but the ^{15}N values are more modest. The utilization of local food sources, both aquatic and terrestrial in nature, is not fully in agreement with the environment and may point to a similar seasonal exploitation of upland territory as the Late Mesolithic Hardinxveld series.

The coastal situation of Schipluiden, near the estuary of the Meuse, favoured the consumption of marine food. This is evident from the isotope values as well. Both ^{13}C and especially ^{15}N are indicative of a largely marine/aquatic diet. The presence of sturgeon may have been important in this case.

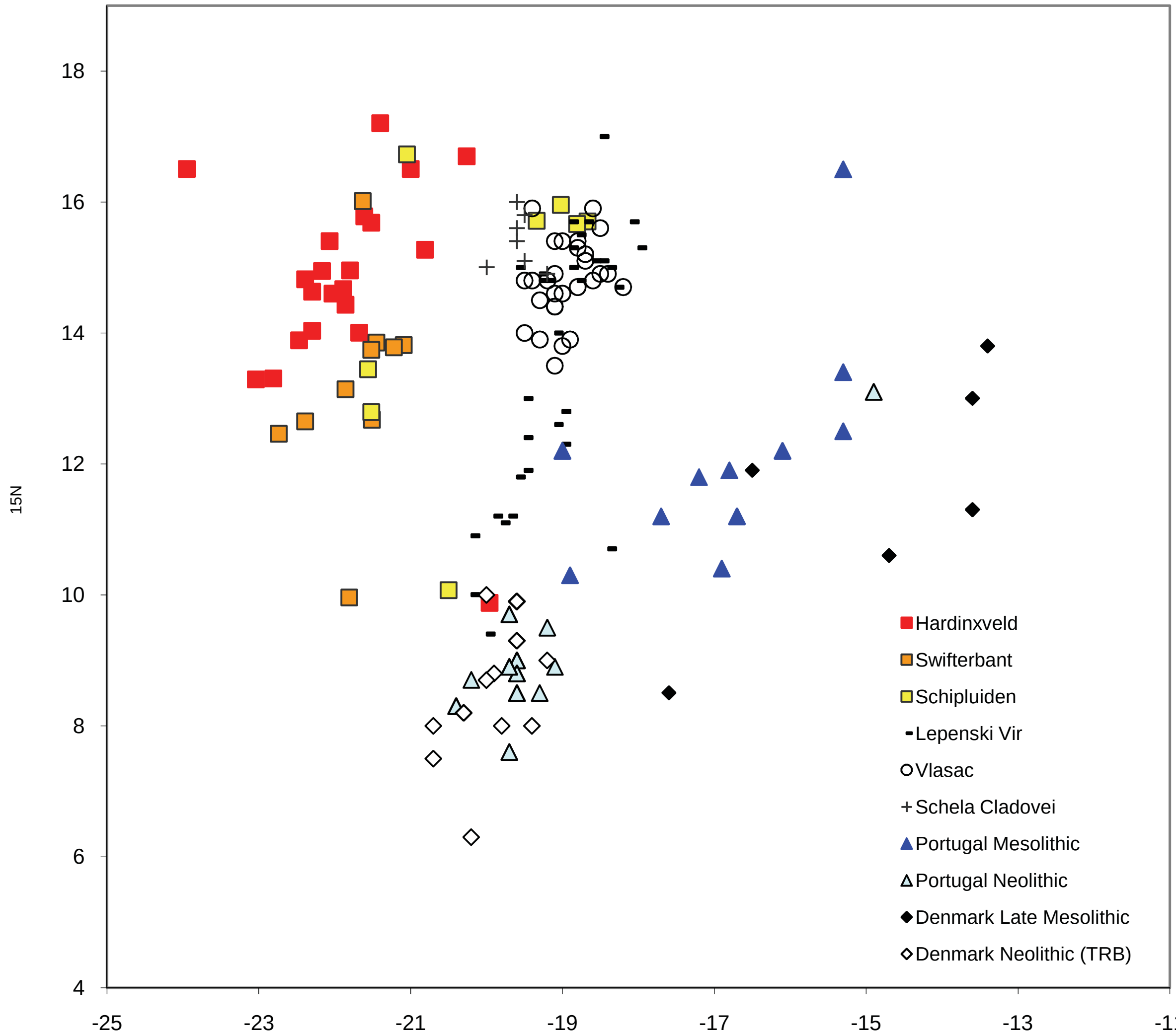

Fig. 14 Stable isotope ratios $\delta^{13}C$ and $\delta\ ^{15}N$ for human bones from Hardinxveld, Schipluiden and Swifterbant (cf. figure 11) compared to those from the Iron Gate sites Lepenski Vir, Vlasac and Schela Cladovei, from Portugal (after Lubell et al. 1994), and from Denmark (after Richards et al. 2003b).

The high proportion of marine and aquatic protein in the diet of the Schipluiden people is in line with the archaeozoological evidence, showing that these people practised an 'extended broad spectrum economy', combining the traditional exploitation of a wide range of natural resources with the 'new' crop farming and animal husbandry, but estuarine fishing must have been of far greater importance than reflected in the recovered remains. The residues from food vessels at Schipluiden confirm this conclusion as having contained aquatic food. The results of Schipluiden are comparable to those of the two millennia older Iron Gates gorge sites of Lepenski Vir and Vlasac, where the consumption of sturgeon and fish roe probably played an important role in the diet as well (Fig. 14; Bonsall *et al.* 1997, 2000; Borić *et al.* 2004). The data derived from the Danish and Portugese Mesolithic and Neolithic sites show a clear change in time in favour of terrestrial food sources (Richards *et al.* 2003b; Lubell *et al.* 1994). The N values are lower compared to our populations of the Lower Rhine Basin indicating the consumption of food from sources that held a lower position in the food chain.

This demonstrates that Neolithisation was still in an initial stage as far as diet is concerned even as late as 3500 BC, almost two millennia after agriculture was introduced by the Bandkeramik farmers in the loess zone of the Rhineland, Limburg and Belgium, less than 200 km to the south.

The richness in aquatic food sources present in the Lower Rhine Basin shows up in the isotopic signature of the populations studied. The composition of the diet with respect to proteins seems to be highly related to the exploitation of the natural surroundings, more than on the available knowledge of food production. Some outsiders display a more terrestrial diet, which is understandable when they originated from other regions with other resources, but some locally born and grown people had a more terrestrial diet. One can think in those cases of a special social position, food taboos or personal tastes which led to a diet lower in fish.

7.6 Conclusions

The mortuary ritual between 5500-3500 cal BC in the Lower Rhine Basin displays a dichotomy, namely burials and above-ground treatment of the corpses.[7] The cemeteries comprise mostly single burials, but double, triple or communal graves also have been identified. These practices may be related to the cause of death, either natural or unnatural and to the traditions of social-cultural subgroups. The burial traditions comply in general with those of contemporary European groups. The isolated scattered human bones recovered from refuse zones may be partly the result of taphonomic processes but can indicate various rituals as well, ranging from excarnation to cannibalism.

The sites concerned are interpreted as base camps that were inhabited by families. The Ypenburg population is best suited to drawing inferences with respect to demography and health. Child mortality was high, which means fertility was high as well, leading to the assumption of population growth. Although the data on diseases and trauma are sparse, physical stress markers on the skeletons indicate a daily heavy workload.

The isotope study of diet reveals a distinct aquatic component for the three populations with variations, which are explained by the exploitation of the local habitat. The presence of outsiders partly explains the heterogeneity of the results, but locally born and grown people also display terrestrial values in some cases. Variation in burial practices sometimes coincides with the isotopic results concerning diet and provenance.

Patterns, in which subgroups are linked with a certain diet and burial rituals, cannot be established at this stage of the research. These results, however, lead to the formulation of new research questions, which incorporate the analysis of dispersed human bones. Efficient sampling strategies are imperative to recover such remains.

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Notes

1. All dates in calibrated radiocarbon years BC.
2. The sites of Mariënberg, Dalfsen, Oirschot and Zoelen, are only described in that section to illustrate the variety in the treatment of the dead. As human bones are either absent or sparse these will not be representative for the underlying population, their traditions and biological parameters – these will remain unknown. Therefore they are excluded from the discussions on the topics on demography, health and diet.
3. Amber was not locally available but could have originated from the ice-pushed tertiary deposits or the coastal area in the Netherlands.
4. The applied methods of the age determination differ per population. These methods include the attrition of the teeth, internal suture closure, the degeneration of the spongy bone structure of the proximal femur and humerus and the degeneration of the pubic symphysis and microscopic evaluation of the femoral diaphysis (for more details on the used methods see the various references on the physical anthropological analyses). This has resulted in unstandardized age intervals. For the purpose of comparison the ages are recalculated and subsequently devided in 5 year age groups. The choice for 5 year instead of, for instance, 10 year intervals is to be able to differentiate the various age intervals of children and subadults below 20 years. The subadult – adult ratio is the main parameter used to compare the mortuary profiles. The mean age at death for men and women is presented but will not be used to draw any conclusions due to the problematic aging methods for adult individuals.
5. Generally the teeth were preserved well, therefore the statements about the occurence of enamel hypoplasia and caries can be seen as representative. See the original physical anthropological publications for detail information on the presence of teeth.
6. Stature is uncorrected for age as the health standard is of importance here and therefore the maximum stature is taken into account.
7. See also Louwe Kooijmans (in press).

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